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Sugar Beet Culture

In the Northern Great Plains Area

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THE CLIMATE and soils of the northern Great Plains are well adapted to sugar beets. The crop has been grown there for more than 40 years. As a result of improvement in varieties and in cultural practices, together with greater use of commercial fertilizer, yields have increased and labor requirements have been reduced.

The sugar beet has demonstrated the importance of soil improvement by crop rotation and by use of barnyard manures. Green-manuring crops have also come into use to offset soil depletion. The results from weed-free crop culture showed decisively the value of the practice.

This bulletin outlines practices in growing sugar beets in the northern Great Plains. It summarizes results of experiments. It discusses effects of climate and soil, and outlines suitable types of rotation and proper manuring practices, including the use of green manure supplemented by commercial fertilizers where not enough barnyard manure is available. It describes the operations involved in growing and harvesting the crop.

Utilization of sugar beet byproducts as feed for animals is stressed as giving a second and highly important return to the farmer.

This bulletin supersedes Farmers' Bulletin 1867, Sugar-Beet Culture Under Irrigation in the Northern Great Plains.

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SUGAR BEET CULTURE IN THE NORTHERN GREAT PLAINS AREA

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INTRODUCTION

Methods of growing sugar beets as described in this bulletin apply to irrigated areas of Nebraska, Wyoming, and South Dakota (fig. 1). Growers in other western areas, especially northern Colorado and eastern Montana, may find the information here given useful as a guide.

In the northern Great Plains the average yield of sugar beets ranges from 12 to 14 tons an acre, with some districts consistently producing larger crops than others. The yields for individual growers in almost all districts may range from more than 20 tons of roots to less than 10 tons an acre.

Some of the practices in growing sugar beets have become standardized. Thus, methods of land preparation and precautions to avoid moisture loss from plowed ground before planting

the crop rather generally follow certain patterns. Other practices have been revised or discarded. Dates of planting, for instance, have been set forward 1 to 2 weeks, and the harvest date has been put off from late September to the middle of October or later. New developments in planting and harvesting equipment have brought about radical changes in practice. Loading sugar beet roots in the field is an example. Some years ago they were scooped by hand from the piles into the truck. Later, pickup loaders were widely used for about 10 years. At present, combines that mechanically lift and top the roots as one operation are rapidly replacing the loaders. Some are equipped for direct loading from the topper to the truck.

Many of the recommendations in the following pages are based on the results of experiments conducted from 1930 to 1948 at the United States Scotts Bluff Field Station, Mitchell, Nebr., and on lands leased from Nebraska growers; at Torrington, Wyo., in cooperation with the Goshen County Experiment Farm of the State agricultural experiment station, and with the Holly Sugar Corp.; and at Belle Fourche, S. Dak., in cooperation with the Utah-Idaho Sugar Co.

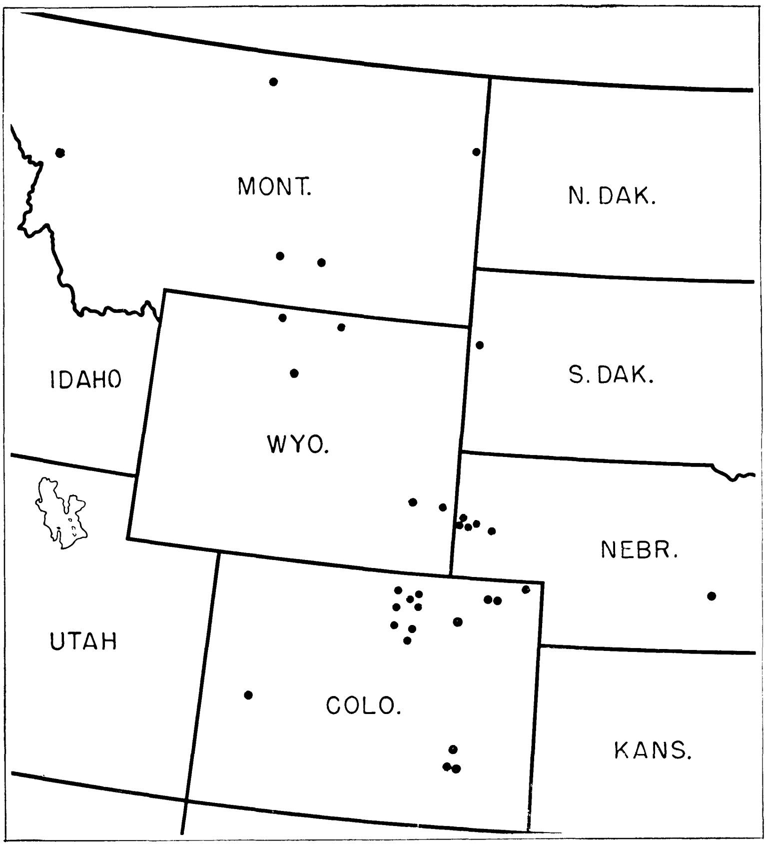

Figure 1.—Beet sugar factories in northern Great Plains and adjacent areas.

EFFECT OF CLIMATE

Temperature, precipitation, sunshine, humidity, length of day, length of growing season, wind, and hail affect sugar beet production. They are the factors that determine the suitability of a district for growing the crop. Seasonal variations in the elements that constitute the climate in the northern Great Plains area affect yields decidedly. The variations may be so great that some seasons are favorable, with yields high, whereas other seasons are unfavorable, with low yields. Rainfall is less essential in irrigated than in nonirrigated areas. Because they affect the moisture conditions of the soil or provide the water for irrigation, rains and snows that fall in a district or on its mountain watersheds have decisive influence. Spring rainfall is depended on for the germination of sugar beet seed in most of this area, although irrigation is employed immediately after planting in a small part of the area to bring about germination.

Weather favorable to overwintering, hatching, or growth of insect pests has an indirect effect on the beet crop. Hot weather may be favorable or unfavorable to its growth, depending on when the temperature rises.

WIND

On the northern Great Plains strong winds are frequent, and growers are aware of the damage done in the spring to bare plowed and fitted fields by removal through wind erosion of valuable surface soil. Nearly all sugar beet growers make furrows between the rows at planting time and during blind cultivation as often as may be necessary to prevent wind damage. They use a 4-row beet drill, equipped with two furrow openers, each of which makes a furrow and two small ridges between alternate rows when the seed is planted. Sometimes the furrows are sufficient to prevent wind damage until the crop has reached the stage where cultivation is needed for weed control. Blind cultivation, however, often is necessary. This cultivation is done on alternate 4-row strips so as to cover the land faster and to leave drill marks that can be used if further cultivation is needed. Small duckfoots or small ditchers are employed. The ditchers follow the furrows made when the field was planted.

Cultivation does less damage to the seed row and is less injurious to the small plants than harrowing. As the beets become larger, knives are used to stir a greater part of the area between the rows. The use of harrows, rollers, and other soil-stirring implements to prevent wind erosion has largely been discontinued (fig. 2).

Most wind damage to sugar beet plants occurs early in the growing season, usually soon after a moderate to heavy precipitation that has destroyed the surface mulch of the soil. Prompt mechanical stirring of the soil surface is the most effective method of combating wind damage. Fast-moving tractors and improved cultivation tools have made it easier to control wind erosion in the fields. The cotyledons (seed leaves) and new leaves of small beet plants are fragile and tender and

are easily cut off or otherwise damaged by particles of sand driven by a strong wind.

Loose seedbeds are responsible for injury to the beet crop from shifting soils. The seed furrow is depressed an inch or more if the seedbed is not firm; drifting soil fills the furrow and may cover the seed too deep. Young beet plants also may be covered by drifting soil, and even a small amount of covering may destroy the stand. The best preventive is a firm seedbed. At Torrington, Wyo., on sandy land and with a loose seedbed, part of a field was planted. Then the drilling of seed was stopped until the rest of the field could be rolled with a corrugated roller. The drilling was continued in less than 1 hour. By actual count, the rolling had increased by 35 percent the stand of beets.

Wind may damage fields in fall and winter. Under old methods of harvesting sugar beets, the loading furrows and piled tops prevented wind damage to beet fields between harvesttime and the period of preparing the soil for the next crop. Mechanical harvesters have eliminated the loading furrows,

Figure 2.—Strip cultivation to prevent wind damage to sugar beet fields. Four sugar beet rows are cultivated and four rows left unworked.

and more beet tops are being siloed in green condition. As a result, the overwinter damage to sugar beet fields has increased.

It is now becoming the practice to furrow beet fields in the autumn after harvest with the cultivator implements used for making irrigation furrows between the sugar beet rows. On very sandy fields and following very severe windstorms, it is sometimes necessary to remake the furrows. Larger furrowing implements are recommended if soils are subject to wind drift.

TEMPERATURE

The sugar beet is now produced where the growing season is approximately 5 months and the mean temperature is about 70° F. for the 3 summer months and slightly lower in spring and fall. Sugar beets do not grow well in periods when the maximum temperatures are about 100°. Very hot weather early in the growing season is not favorable to them.

Sugar beets are more resistant to frost injury than some other crops grown in the irrigated districts. Temperatures as low as 27° F. usually do not injure the plants either in their early growth in the spring or as they mature in the fall. Small plants just coming through the surface of the soil are, however, particularly sensitive to frost injury. Aside from this brief stage of growth, if the ground is moist and the seedlings have emerged and are developing true leaves, it is not often that a drop in temperature to as low as 25° will cause the serious loss of a stand. Young plants are injured more by prolonged cold, wet periods without sunshine than by frost.

In the northern Great Plains region, cool periods in the fall favor storage of sugar in the beet root. Temperatures below 26° F. usually cause foliage injury. Following such injury to the tops, a period of warm weather may bring about a growth of new leaves and a sharp decline in the sucrose content of the roots.

PRECIPITATION

Annual precipitation in the northern Great Plains sugar beet area varies from less than 6 to more than 20 inches, with wide variations from year to year. There are also wide variations in the monthly distribution of precipitation. Sometimes the total spring and summer rainfall is made up chiefly of scattered light showers. These are of little benefit, as showers of less than ½-inch precipitation are of little value to the growing crop.

Where spring rainfall normally is inadequate for seed germination, growers irrigate immediately after planting and usually obtain good stands. Where there usually is sufficient moisture for germination, either from water stored in the soil or from timely rains, irrigation is not often used at that time. Fields with poor stands frequently found in these districts are the result of improper seedbed preparation that has allowed excessive loss of soil moisture. In seasons when spring rainfall is subnormal, failure to irrigate brings about uneven and late germination.

Germination of the seed usually depends on spring rainfall and on moisture in the soil. Therefore, it is important to prepare the seedbed so as to conserve as much soil moisture as

possible and to plant early in order to benefit from early spring rains.

Throughout the sugar beet districts of the northern Great Plains, the common practice is to disregard rainfall in July, August, and September and apply irrigation water at regular intervals.

Snowfall is usually not heavy in this area; the average precipitation for December, January, and February is about ½ inch a month. It helps mellow the soil and contributes slightly to the soil-moisture reserve. Heavy snowfall on the mountain watersheds provides water for summer irrigations. The depth and period of melting of the snow are important, or even critical, factors for crops dependent on this water source. Snow falling on sugar beet fields before harvesting is completed greatly increases harvesting costs and may cause heavy crop losses. Some types of modern harvesting equipment can operate even when fields are covered by a few inches of snow, thereby reducing this crop hazard.

HAIL

Hailstorms are more frequent in the northern Great Plains than in any other sugar beet growing area in the United States. Because of its form and growth habit, the sugar beet can withstand hail better than any other crop grown in the area. The roots, being protected by the soil from hail damage, are soon able to grow new tops, even though the foliage is completely destroyed. The replacement of leaves requires 2 to 3 weeks. Unless the plants are very small, a sugar beet crop is seldom damaged more than 20 or 25 percent by hail during an entire season. On the other hand, a complete loss of small-grain, corn, and bean crops frequently results from hail. As no method of protecting field crops from hailstorms is known, it is advantageous for the farmer to maintain each year the proper proportion of his acreage in the crop that suffers the least damage.

If hail hits before the beets have reached the 4- to 6-leaf stage, or immediately after thinning, many plants may be killed. When a greater growth has been attained, as by mid-July, 95 percent of the plants will survive even the most severe hailstorms.

Damage to sugar beets by heavy hailstorms is usually overestimated. Damage by hailstones that make small holes in the beet leaves but do not completely strip the plants, however, is often underestimated. Loss of leaf surface and the growing of a new flush of leaves reduce the rate of root growth, retard the maturity of the plant, and delay sugar storage in the roots.

Regular cultivations, weed control, and frequent light irrigations do much to assist the recovery of the hail-damaged beet crop. Side dressing with fertilizer in the first half of the season supplies plant nutrients necessary for production of new leaves.

LAND SELECTION

Land selected for growing sugar beets should have better-than-average fertility. The cost of beet production is relatively

high and above-average yields are usually necessary to assure an adequate return to the grower. Several other field characteristics need careful consideration in selecting the land, such as contour and slope, soil type, and physical condition of the soil. The place of the sugar beet in the crop sequence and the condition of the soil as to insect and disease infestation, weeds, and other factors are important.

Fields with unfavorable factors often can be made suitable for sugar beet growing by use of proper agricultural methods. During the improvement stage, however, it usually is advisable to grow crops costing less to produce.

CONTOUR OF LAND

Contour of the land is very important in an irrigated area where the water is distributed to the crop by gravity flow. In some modern systems water is distributed under pressure in pipes and sprinkled over the land, but irrigation by overhead sprinklers or by rotating nozzles is not the common method.

Sugar beet rows are usually 20 inches apart, and ditches or furrows between them cannot be more than 3 or 4 inches deep. In the Far West, sugar beets are planted on ridges, so that deeper furrows can be used between the rows. In the northern Great Plains, however, this practice has not been adopted to any extent.

Very slight variations in surface levels of a field may seriously interfere with the proper gravity flow of irrigation water. It is advisable to use rough fields for growing grain, hay crops, or wide-row crops, such as potatoes, instead of sugar beets, until the land can be properly leveled. Modern land-leveling machinery now makes it possible to improve the contour of many fields so that they are suitable for sugar beets (fig. 3). The best contour of land for sugar beets is a gentle, even slope on which water can be run between the rows in furrows about

Figure 3.—Modern land-leveling machinery used to improve contour of fields.

3 inches deep for a distance of 300 to 500 feet. On lands that are heavy and do not wash easily, slightly longer runs of water are often made.

On steeply sloping lands, irrigation water must be run for long periods to insure adequate penetration of the soil. Hence, steep slopes are not suitable, as the water must be run in the irrigation furrows several times during the season and the repeated flow of water between the rows on steep slopes may wash deep furrows and bring about serious soil displacement. In many sugar beet fields throughout the irrigated areas, dry spots are noticeable, most often where the slopes of the land are abrupt.

SOIL TYPE

The irrigated areas have many types of soil, almost all alkaline, ranging from heavy clay, medium clay, silt, or sandy loams to pure sand. Adobe, volcanic ash, and gravelly soils are also found. Sugar beets can be grown on a wide range of soil types. Some soils, however, require very skillful farming and careful handling for profitable yields. Water rights are often more important than soil type.

Light and medium sandy loams are best adapted to sugar beet culture because they are easily handled and least subject to serious crusting. They usually produce the best yields. Light, loose soils absorb water rapidly but have less water-holding capacity than heavier soils. The heavier soils are penetrated less quickly, so that an irrigation requires longer periods of water flow. The capacity of a soil to absorb water is of prime importance in determining appropriate irrigation practices.

Heavy clay soils are better adapted to sugar beets under irrigation than under natural rainfall. Clay soils are difficult to handle when either wet or extremely dry. As the irrigated regions do not have a heavy rainfall, the clay soils are not often excessively wet, and proper irrigation can usually keep such soils from becoming too dry. Clay soils are more subject to crusting than lighter soils, but less subject to wind damage.

Sugar beets generally yield better on the heavier soils, but almost the same production may be obtained on the sandy soils by early planting, frequent irrigations, and adequate use of barnyard manure. Plants germinate earlier in sandy soils and produce a more vigorous growth for a few weeks in the early part of the growing season. During hot weather, however, when the demand for water is greatest, the beets on heavier soils usually make the better growth. The crop as grown on the sandy soils requires frequent irrigations from midseason to early September if wilting is to be avoided.

The growing of the crop on gravelly soils presents many of the problems found with sandy soils; furthermore, soils of this type frequently are low in fertility. The mechanical harvesters when used on gravelly soils sometimes pick up stones about the size of a sugar beet or larger. These may be a source of serious

damage to the harvesting equipment and to the cutting knives at the beet sugar factory.

PHYSICAL CONDITION OF SOIL

The physical condition of the soil depends to a great extent on the soil type. Soil type is not subject to change except in isolated instances in which the land is filled or the surface soil is removed in leveling. On the other hand, properly planned agricultural practices can bring about soil improvement by their effects on soil tilth. Rotation, cultural practices, use of barnyard manures, green manuring, and irrigation methods have a definite influence on the immediate physical condition of the land.

This is evident in the irrigated districts of the northern Great Plains. Some lands here have been irrigated for more than three-quarters of a century and still comprise some of the best agricultural lands of the area. On other farms, in irrigated districts that were among the last to be developed, irrigation water has been available for less than 35 years. Some of these farms are in good physical condition, but others are in much worse condition now than when the first crops were grown. On some farms with sandy soil practically all of the original humus has been exhausted and the soils are now light, blowing sands. In sharp contrast to conditions on the abused farm lands, the soil on nearby homesteads has been greatly improved by windbreaks that prevent wind erosion and by consistent addition of humus-building materials. On all soil types in the area, similar contrasts between humus exhaustion and soil building exist.

Soil fertility in the irrigated districts seems to be closely related to the physical condition of the soil. The fields in good physical condition are the ones that now grow good crops of sugar beets; those where the soil structure (physical condition) has been permitted to deteriorate so that water-storing capacity has been lost show a corresponding decline in yields. The evidence is significant that continued use of green-manure crops and application of barnyard manure improve the physical condition of all soils. As might be expected, the most decisive responses to these practices are on either the extremely light or the extremely heavy soils.

SUBSOIL

The ideal subsoil for a sugar beet field has good water-holding capacity but nevertheless permits ready drainage of excess water. The topsoil layer should be 2 feet or more thick. Good drainage is as important where irrigation is practiced as where crops are grown under natural rainfall. Neither a hardpan subsoil nor a very loose subsoil is desirable for sugar beets. The hardpan prevents drainage of excess water applied during

irrigation, so that it is practically impossible to irrigate a field amply without some excess water collecting in the lower-lying parts.

Sugar beets are a deep-rooted crop; hence, the height of the water table in the subsoil can affect root growth. An excessively high water table may bring about forked, turnip-shaped roots because of injury to the main root. Under conditions of light rainfall and excessive evaporation, a high water table tends to bring about such an accumulation of alkaline substances in the topsoil as to seriously retard growth. In fields where the water table is within 3 feet of the surface, only light runs of water should be made.

CROP ROTATION

The benefits from a proper crop rotation include: (1) A more varied source of farm income; (2) abundant feed for livestock, encouraging the inclusion of livestock in the farm program; (3) more even distribution of the labor load in crop production throughout the season; (4) apportionment of the water demand by the various crops; (5) less damage by diseases and insects; and (6) better weed control.

Crop rotation alone cannot over a continuous period of years produce maximum yields of any of the crops common to these districts. It is necessary to apply manures and fertilizers regularly if gradual soil depletion is to be avoided. Crop rotation does not appreciably build up the plant-food content of the soil, except as the residues from a legume crop add nitrogen. Some changes are made in the availability of minerals in the soil. In a proper soil-management program, barnyard manure is employed along with commercial fertilizers to supply needed plant-food elements. These methods of soil improvement are closely interrelated, as in a well-balanced system certain crops are grown to feed livestock and the manure produced is returned to the soil.

The significance of crop rotation in this area is very well shown by the unfavorable effects of growing beets continuously in certain fields over a long period.[1]

As a rule, single cropping for a number of years intensifies the factors that bring about low yields. Plant diseases and insects are increased, soil fertility is lowered, and soil structure is impaired. With sugar beets, failure to practice crop rotation has almost always depressed yields.

Continued growing of sugar beets often has resulted in the development of the sugar beet nematode to serious proportions in

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[1] The following U. S. Department of Agriculture publications, available only in libraries, give detailed information on rotation studies at the Scotts Bluff, Nebr., Belle Fourche, S. Dak., and Huntley, Mont., field stations of the Bureau of Plant Industry, Soils, and Agricultural Engineering: Tech. Bul. 512, Irrigated Crop Rotations in Western Nebraska, 1912–34; Tech. Bul. 571, Irrigated Crop Rotations at the Huntley (Mont.) Field Station, 1912–35; Tech. Bul. 454, Agricultural Investigations at the Belle Fourche (S. Dak.) Field Station, 1926–32; and Cir. 779, Effect of Crop Rotation and Manure on the Yield and Quality of Sugar Beets, United States Scotts Bluff (Nebr.) Field Station, 1930–41.

the soil. Such infestations make sugar beet growing unprofitable unless, through a long-time rotation system in which nonhost crops of the nematode are grown, the sugar beet nematode population is drastically reduced. After such a regime for control is established, sugar beets cannot be grown more than once in 5 or 6 years, and the other crops in the cycle must be nonhost plants. Occasionally sugar beets have been grown continuously for several years with good yields in fields where manure has been applied in ample quantities. Such fields may have escaped the introduction and subsequent increase of the nematode. Other fields in the same districts with a similar history of intensive cropping with sugar beets have become so infested with the sugar beet nematode that yields are seriously reduced.

As a control, or check, in the crop-rotation experiments at the Scotts Bluff Field Station, one plot has been planted to sugar beets each year for more than 35 years without any applications of manure. Acre yields have fallen from more than 15 tons to about 5 tons as a result of single cropping. Many plants died between thinning and harvesttime, the heavy death rate evidently being caused by depleted soil and increased effects of sugar beet diseases. The fields were given close supervision, and there was no return of "dump" dirt to the plots. The results show that, even with the absence of the nematode, continued cropping without the use of manure is not a proper method of growing sugar beets.

In the tests, rotations consisting only of soil-depleting crops similarly gave poor results as measured by the acre yields of sugar beets. For example, in 2-year rotations, in which sugar beets alternated with such crops as oats, wheat, corn, barley, or potatoes, the acre yields of sugar beets fell from the general average of 15 tons to about 7½ tons.

The introduction into the rotation of soil-building legume crops such as alfalfa and sweetclover, the plots not being pastured and manure not being added, has kept the yields at a fairly high level. Similar results have been obtained in many districts of the northern Great Plains. On certain soil types, however, no definite benefits have resulted from growing and turning under legume green manures. The difference in the response to the legume crop may be caused by differences in the phosphate content of the soil. Legume crops are heavy feeders on phosphate, but they do add to the nitrogen content. Growing legume hay crops on soils low in phosphate has been found of little benefit to the sugar beet crop unless manure or phosphate is added.

At the Scotts Bluff Field Station, the use of alfalfa in rotations with sugar beets and other crops has been sufficient to maintain for 35 years an average acre yield of about 15 tons. The addition of manure at the rate of 12 tons an acre, whenever sugar beets were grown, has produced yields of 17 to 18 tons of beets an acre. When the experiments were started the original application of manure raised the production of beets to about the same level. Therefore, the gains in yields by the use of legumes and manures were quickly obtained and maintained, but pro-

duction does not continue to climb unless greater quantities of manure are added, along with adequate amounts of phosphate and nitrate fertilizer.

Comparable studies at the Belle Fourche, S. Dak., Field Station gave somewhat different results from the inclusion of alfalfa in rotations containing sugar beets. At the start of the rotations, the sugar beet yields were 4 or 5 tons below the initial yields at the Scotts Bluff station. Inclusion of alfalfa in the rotations resulted in about a ton increase in acre yield of sugar beet roots. The plots receiving manure applications showed a definite increase in yields. During the later years of the experiments, the sugar beet rotations at the Belle Fourche station, especially those in which alfalfa was included, showed serious depletion of the phosphate in the soil. Addition of this element to the soil by commercial fertilizers greatly increased the yields.

SELECTING A ROTATION

The highest yields of sugar beets are obtained when the crop is grown in a rotation that includes legumes and has manure or a suitable commercial fertilizer applied to the sugar beets. The clean culture given the crop makes the sugar beet a very valuable component of a rotation because the weed population of a field is reduced. This is very noticeable in crops that follow sugar beets in the rotation, especially the small-grain crops.

In the selection of rotations for the irrigated districts, water requirements of the various crops must be considered. Grain and alfalfa need water earlier in the season than potatoes or sugar beets. Sugar beets and alfalfa require more water than small grain, potatoes, or corn.

Alfalfa is the principal irrigated hay crop in the northern Great Plains; sugar beets, potatoes, wheat, and beans are grown for sale off the farm; barley, oats, and corn are grown as feed crops; sweetclover and alfalfa are used to some extent for pasture.

Various rotations employing these crops are needed to meet different farm requirements. Alfalfa is usually grown for 3 years after being started with a small-grain crop. The seeding is made with the small grain that serves as a nurse crop for the alfalfa. A 6-year rotation commonly employed in the area consists of small-grain 1 year, alfalfa 3 years, potatoes or corn 1 year, and sugar beets 1 year. In the districts suited for their culture, potatoes usually are the best crop to follow alfalfa. Their late planting date permits more green growth of the alfalfa before plowing under in the spring to prepare the ground for potatoes. It is common practice to lengthen any rotation by growing sugar beets for 2 years following the potato crop, providing the soil is free from the sugar beet nematode and providing manure is used. Variations may be made in the rotation in order to introduce other crops that are profitable in a particular area.

A 3-year rotation followed on many farms consists of small grains seeded to sweetclover 1 year, the sweetclover being plowed late the next spring, followed by potatoes 1 year and

sugar beets 1 year. These rotations are shown in the following schedule.

Year of rotation:	*6-year rotation*	*3-year rotation*
First	Small grain with alfalfa	Small grain with sweetclover.
Second	Alfalfa	Potatoes (sweetclover plowed under about June 1).
Third	do	Sugar beets.
Fourth	do	Small grain with sweetclover.
Fifth	Potatoes (alfalfa plowed under about June 1).	Potatoes (sweetclover plowed under about June 1).
Sixth	Sugar beets	Sugar beets.

LIVESTOCK MANURES

The mineral reserves of the soil are drawn upon to build plant substance. As each crop is grown and removed, soil reserves are depleted according to the drafts that the crop makes upon the different elements and the size of the crop. Continued removal of crops without replacement of these elements depletes soil fertility and, as a consequence, crop yields decrease. Best results in farming are obtained through the use of methods that return the nutrient elements and organic matter to the soil. Proof of this is afforded by the fields which, after being farmed nearly three-quarters of a century, now produce as well as when first brought under cultivation. In contrast, nearby lands of equal yielding capacity when first farmed are now producing low yields because of neglect in maintaining soil fertility.

The soluble soil minerals are immediately available for use by plants. They are subject to loss by leaching where too much water is applied. In the soil there are also insoluble chemical reserves that slowly become available as chemical changes make them soluble. Phosphorus, the very important plant-food element that is added as a commercial fertilizer, may revert largely to an insoluble calcium phosphate on highly calcareous soils, or it may become unavailable to plants on soils low in organic matter. To counteract these conditions, such soils need to have their humus content built up and they may require yearly applications of phosphorus. These are the soils that show striking results from a combined application of manure and phosphate fertilizer.

Livestock manures contribute plant-food elements to the soil, add to its humus content, and improve its physical condition. Increased yields of crops are obtained after the application of manures, but the increases cannot be explained solely on the basis of the chemical content of the manures added. Addition of barnyard manure quickens microbial activity and thereby sets up complex reactions that serve to release for plant use the plant-food reserves of the soil. The beneficial effects on the

soil from green manures are probably the result of similar processes.

METHODS OF MANURING

Sugar beets in the irrigated area respond readily to applications of barnyard manures. Tests indicate that the manure applied to the sugar beet crop gives a higher return than is obtainable from its use with any other crop grown in the northern Great Plains. Accordingly, the manure produced on a farm in this area is nearly always used to fertilize the fields in which sugar beets are grown, applications being made immediately before field preparations begin (fig. 4).

Some growers pasture livestock on legume crops and corn preparatory to fitting the land for sugar beets. The common practice, however, is to make use of feed lots from which the livestock manure is later hauled to the fields and spread. The

Figure 4.—Spreading manure before plowing for sugar beets.

manure should not be hauled from the feed lots until it is possible to spread it on the soil and to plow it under without delay.

On about a quarter of the sugar beet acreage of the northern Great Plains, livestock is pastured on the tops left in the fields after harvest. Although most of the manurial value of the tops is retained by such pasturing, much of their feed value is lost and the manure is not available for hauling to the field where sugar beets will be grown next year. As tops hauled from

the field, cured, and used in a feed lot have a higher feed value for stock, pasturing of beet tops is giving way to lot feeding. Another method sometimes used is to feed sheep for a few weeks in temporary feed lots on fields where sugar beets are to be grown the next year. The fresh beet tops are collected and hauled to the feeding pens. This adds manure to the land, but the compacting of the soil may be detrimental.

VALUE OF LIVESTOCK MANURE

The question of the comparative value of manure from different kinds of livestock is often raised. A 4-year test at the Scotts Bluff station revealed no great differences in yields of sugar beets attributable to kinds of manure used. The check plots received no manure; the treated plots received applications at rates of 6, 12, 18, or 24 tons an acre. Manures from horses, cattle, and sheep were compared, but quantities of each kind were so adjusted that the same weight of dry matter of each was applied to an acre. With moisture content controlled, differences as to animal source were not significant.

A determination of the quantity of manure produced for each 1,000 pounds live weight of horses, cattle, or sheep, under conditions where all the manure was recovered, showed that the differences in gross quantity vary more than net quantities of nitrogen, phosphorus, or potash. The manurial value for each animal unit on the farm is influenced by the bedding used and the methods of handling the manure. Ample use of bedding and immediate spreading of the manure conserve more of manurial values than other methods. The manures accumulated in feed lots are trampled and packed, and thus are reasonably well conserved. In the irrigated districts where feed lots are usually dry, the storage of manure in the lots is common practice. Manure from dairy cattle and from wet feed lots is high in moisture. As a rule, manure from sheep feed lots is lower in moisture than that from cattle feed lots.

The gain in crop yield shown the first year a field is manured does not represent the total gain from an application. Benefits traceable to manure are apparent over a period of years, usually gradually diminishing in amount. This is true whether the crops are sugar beets, grain, alfalfa, or corn. Returns in the form of increased sugar beet tonnage, amounting to from $5 to $10 for each ton of manure applied, were estimated on the basis of experience in 1948 on many farms. On such a basis, the manure from each 1,000-pound animal unit on some of the irrigated farms is worth as much as $40 a year. These figures are affected greatly by the rates of application, the value of the crop produced, and the state of fertility of the land to which the manure is applied. Crops that have a high acreage value, such as sugar beets and potatoes, give the greatest returns from the use of manure. Plots to which manure is applied at the rate of 6 tons an acre show a greater percentage increase than those on which it is applied at the rate of 18 to 24 tons an acre. Land of low fertility usually responds better to the use of manure than land of high fertility. In the test at Torrington, Wyo., where the untreated portions yielded 8 tons of beets an

acre, the use of 12 tons of manure an acre increased the yields of sugar beets by 4 tons an acre the first year, whereas at Scottsbluff, Nebr., on a field that yielded 16 tons an acre without treatment, the use of 12 tons of manure an acre increased the acre yield of sugar beets by only 2 tons.

At the Scotts Bluff Field Station, in three different rotations in which no legume crops were included, manure was used on each beet crop. The yield of sugar beets over a 25-year period was increased by an average 7.2 tons an acre over that of similar rotations that did not have the benefit of manure. In tests of the same type at the Belle Fourche, S. Dak., Field Station, manured fields produced approximately 5½ tons of beets an acre over unmanured fields.

At each station there are two 6-year rotations that include sugar beets. One rotation consists of sugar beets 1 year, alfalfa 3 years, potatoes 1 year, and oats 1 year, with 12 tons of manure an acre applied before planting sugar beets. The other rotation is the same as to crops, but no manure is applied before planting the beets. The latest summaries show that the manured plots are producing sugar beets at a rate of approximately 5 tons an acre more than the unmanured plots.

QUANTITY TO APPLY

Although the greatest percentage increase in yield of sugar beets for each ton of manure used was obtained when only 6 tons an acre a year were applied, a higher total production followed the application of 12 tons an acre a year, together with a more efficient use of land and manure. With the 12-ton rate of application, the acre yield in terms of sugar produced was as great as from the use of 18 or 24 tons an acre. The larger applications of manure produced only slightly higher tonnages of roots, and the beets had a somewhat lower sucrose content. The general recommendation is to apply not more than 12 tons of manure an acre to land of average fertility for each sugar beet, corn, or potato crop. In a 6-year rotation with 3 years of alfalfa, one application of manure at the rate of 12 tons an acre is sufficient to maintain yields at a reasonably high level. Where the supply of manure is limited, it is better to dress lightly on the entire sugar beet acreage than to apply the manure heavily on only part of the beet lands. Since 1940 application of commercial fertilizers to sugar beets has been found profitable; it is on the increase. Use of manure has fallen off because of the production of more crops for immediate sale and removal from the farm, with a corresponding decline in the production of feed crops.

In the irrigated districts, from 20 to 30 percent of the acreage of a farm is commonly used each year for the sugar beet crop. Thus, on an 80-acre farm, from 15 to 25 acres of sugar beets are grown annually. To produce a heavy crop this acreage in sugar beets needs from 180 to 300 tons of manure a year. Not enough livestock is kept on the average 80-acre farm in this area to produce this amount of manure, and what is produced is not always efficiently cared for to conserve its full value. Therefore, livestock manures must be supplemented with green manures

and commercial fertilizers if the best yields of sugar beets are to be obtained.

Growers are fast becoming aware that the present yields of sugar beets could be increased by manuring the fields to the extent necessary for the proper maintenance of soil fertility. The total tonnage now produced in a district could be produced on a smaller acreage properly manured and fertilized. The present average yield of 12 to 13 tons an acre undoubtedly could be increased by 25 to 50 percent if improved practices were followed on all farms and each acre of sugar beets grown received adequate applications of manure and fertilizer.

GREEN MANURES

ALFALFA

Alfalfa and sweetclover are the principal crops used for green manuring in this area. A very large acreage of alfalfa is grown for hay. When a field of alfalfa is to be discontinued, a heavy green-manure crop should be grown and plowed under late in the spring. As sugar beets are planted early, potatoes, corn, beans, or other crops are grown immediately after the green manure is plowed under and followed by sugar beets the next season.

Another practice is to plow under alfalfa late in summer or fall without making a third cutting for hay. A beneficial effect of the green manuring usually is apparent on the crop that follows. Here again it is best that some other cash crop immediately follow the alfalfa and the sugar beet crop be deferred for one season.

In this area the crops that show the greatest response to applications of phosphate fertilizers are alfalfa and sugar beets. Sugar beets grown after several years of cropping a field with alfalfa often show poor growth and may show the foliage and root injury attributable to phosphate deficiency. Phosphate fertilizer should be applied to all fields where sugar beets are to follow alfalfa.

In some sections the most common method is to break up old alfalfa sods after a close cutting of hay in late summer or fall. The alfalfa is lightly crowned and then turned under. Unless special precautions are taken to kill the crowns by shallow plowing, followed by drying, the alfalfa may persist as a weed. It is easier to kill alfalfa by plowing when the plant is actively growing than when it is semidormant.

Although it is recognized that alfalfa sods handled so as to avoid renewed growth from the alfalfa plants must sometimes be used for sugar beets, the disadvantages of this practice should be clearly understood. Contrary to popular belief and some published recommendations, sugar beets grown on alfalfa sods have usually given mediocre to poor yields. Frequently the so-called alfalfa sods are very old alfalfa fields that have become excessively grassy. It is difficult to prepare these soils so as to obtain a firm seedbed, free from air pockets. The green-manure and nitrogen values commonly expected from alfalfa are not obtained in any great measure, because plowing is usually done in

late fall or early winter, when the fields are relatively bare, or else old alfalfa fields are plowed and on them the actual stand of alfalfa may be sparse. The nitrogen supply of such fields often is low, in sharp contrast to the abundant nitrogen supply from young, full stands of alfalfa. The sequence, alfalfa-sugar beets, has frequently been associated with poor stands of beets because of damping-off, commonly called black root. Root rots later in the season also are serious when sugar beets follow alfalfa. Damage from white grubs, wireworms, and cutworms is more severe when alfalfa sods are used for sugar beets.

The problem of utilizing alfalfa fields to the full is pressing in the entire northern Great Plains area. Where grown in addition to sugar beets, cash crops very profitably can immediately follow the alfalfa crops, the beets appearing later in the rotation. Here the problem is only to utilize fully the green growth obtainable from the legume. When sugar beets must follow alfalfa, the green manure should be turned under before September and speedy decomposition brought about by irrigation of the field.

SWEETCLOVER

Sweetclover has come into widespread use as a green-manure crop and when so used is seldom cut for hay. A common practice is to plant sweetclover with a nurse crop of small grain. If the sweetclover is plowed under the same year, not much benefit results, as the late-summer seasons are usually dry and the sweetclover may make only a scanty growth after the grain is cut. If a sweetclover field is to be planted with sugar beets reasonably early, the sweetclover must be fall-plowed, or, if spring-plowed, must be turned under before its spring growth has started. As with alfalfa, poor stands of sugar beets commonly result when sugar beets immediately follow sweetclover. When plowed in late fall or early spring, the sweetclover very often persists as a weed. Hence, for a relatively small amount of green manure, the sugar beet grower is inviting many difficulties.

There is a widespread practice of permitting sweetclover to grow to a height of 8 to 10 inches before spring plowing. The planting of sugar beets must be delayed at least 1 month in order that a sizable quantity of green manure may be added to the soil and the sweetclover be more completely killed when it is plowed under. It may be difficult to obtain a good seedbed, and irrigation must promptly follow planting to assure proper germination of the beet seed. Although later plowing of sweetclover may give much better stands and better yields than are obtainable with early plowing, neither practice is recommended. As a rule, subjecting the valuable beet crop to such hazards can be avoided. Thus, a potato or other late-planted cash crop may be grown the first year after sweetclover. The sweetclover may be permitted to make a spring growth of 2 to 4 feet before it is plowed under, and then a crop such as potatoes may be planted. The following year the soil is in excellent condition for sugar beets. In tests at the Scotts Bluff station, this method

has given yields of sugar beets equal to those obtained on lands where sweetclover was pastured a full season. The increase above the yield of plots planted to sugar beets immediately after a green-manure crop was plowed under sometimes amounted to 3 to 5 tons an acre (fig. 5).

PASTURING ALFALFA AND SWEETCLOVER

Alfalfa and sweetclover may be pastured for a full season before being plowed under. Although less green manure is obtained by this method than when the legume crops are not pastured, the livestock manures that are added to the soil almost make up for the loss of green manure.

Pasturing as a means of harvesting alfalfa, sweetclover, and some other forage crops is on the increase. Corn harvested by being pastured to sheep and hogs produces manure that greatly

Figure 5.—Turning under a heavy growth of sweetclover to serve as green manure.

benefits the soil. Feeding sheep in cornfields has proved satisfactory when dry hay is fed also to prevent too much grain consumption. The common practice, however, is to pasture cattle or hogs on alfalfa or sweetclover. Satisfactory gains in the livestock come from this type of feeding. When livestock is put into the field early in the season and not removed, bloating seldom occurs, in contrast to results from occasional pasturage of these crops. The yields of sugar beets grown on land on which legumes have been pastured compare favorably with those from land that has had a heavy green-manure crop plowed under.

Also, on many soils the yields are very similar to those obtained from barnyard manure applied at the rate of 12 tons an acre.

Efficient use of legumes for pasturing requires a planning of crops so that fields regularly become available for the purpose. Alfalfa can be pastured during the entire season and for more than 1 year. The usual custom is to grow alfalfa for hay for a limited period and then to pasture it 1 year before plowing the field. Sweetclover does not provide pasturage for more than 1 year.

With a 3-year rotation, a sweetclover field started the previous year provides pasturage early in the season and until the new planting of sweetclover started in small grain is ready. Planting a field each year provides an almost continuous pasturage during the growing season. In pasturing livestock on either alfalfa or sweetclover, fences within the field are desirable. They make it possible to confine the animals for a few days in one part of the field while other parts are permitted to grow. They also keep down damage that comes when livestock trample recently irrigated fields.

Bromegrass pastures, or bromegrass- and alfalfa-mixed plantings, are coming into increased use. The mixed plantings can also be used for hay. Such sod pastures make excellent lands for sugar beets the second year after the land is returned to cultivated crops.

COMMERCIAL FERTILIZERS

Commercial fertilizers were not used for growing sugar beets in the irrigated districts of the northern Great Plains until the late 1920's, as it was generally believed that they would not increase yields. The soils here are extremely variable. When first brought under cultivation, they contained quantities of phosphate and potash, largely in insoluble forms. Certain soils were very high in calcium. The phosphate supply in many of the soils has become low. The potash supply is probably still adequate. As culture of crops has proceeded the nitrogen content of the soils has tended to go down. This decrease has been offset largely by growing legumes, which supply nitrogen when plowed under, and by returning manures produced by the feeding of legume hay. Nitrogen fertilizers have also been used to advantage. The cost of such fertilizers is to be reckoned with in determining their value as a source of nitrogen, as compared with legume crops turned under.

Use of nitrogen fertilizers increased rapidly after World War II. It is now common practice to side-dress crops of sugar beets, potatoes, or beans with 100 pounds or more of ammonium sulfate or ammonium nitrate. Nitrogen fertilizers increase the root and leaf growth of sugar beets, but seldom the sucrose content of the roots. Application of from 100 to 300 pounds an acre of an approximately 10-20-0 fertilizer is becoming common for sugar beets.

The principal fertilizer element necessary on soils in this general area is phosphate. It should be used wherever field tests indicate that it gives profitable returns. Soils are now tested in the laboratory for available phosphate; from the results of

the tests the response from phosphate fertilizers is predicted. In general, the most reliable method of finding whether phosphate fertilizers induce profitable response to sugar beets is to make reasonably heavy applications to strips in the field and compare the yields from treated with those from untreated strips.

Certain factors may be taken into account in working out an adequate fertilizer practice. A ton of sugar beets removes from the soil approximately 4 pounds of nitrogen, 1.5 pounds of phosphate, and 6 pounds of potash. A ton of tops and crowns contains slightly larger quantities of these elements, but, as they usually are fed on the farm, these plant-food elements are partially returned to the soil. A 15-ton sugar beet crop removes about the same number of pounds of nitrogen and phosphate from an acre of ground as is removed by a 300-bushel crop of potatoes, a 50-bushel wheat crop, or a 70-bushel corn crop. The potash requirement of the root and tuber crops is greater than that of the grain crops. An alfalfa crop of 5 tons an acre contains about four times as much nitrogen as a 15-ton crop of sugar beets, but this nitrogen is largely obtained from the air except in old alfalfa fields. The nitrogen content of the soil is generally built up as leguminous crops are grown, but phosphorus and potash are seriously depleted when hay is removed from the land. Fields that have been in alfalfa are very likely to require phosphate fertilization before good sugar beet crops can be grown. The grain crops remove much less potash than sugar beets or potatoes, but, for general purposes, in soils of high potash content this is not of immediate consequence.

Figures on minerals removed from the soil show that heavy yields of the commonly grown crops deplete soils of phosphorus, a fertilizing element whose native supply in the soil frequently is relatively low. For this reason fertilizer practice must concern itself primarily with adding adequate quantities of phosphate to the soil.

The common rate of application of phosphate for growing sugar beets is 100 to 200 pounds an acre of treble superphosphate, carrying from 43 to 45 percent of available phosphoric acid. If all the phosphate could be appropriated by the sugar beet, this amount would be ample to produce a crop of 15 tons or more. Specific recommendations for soils of the area, or even of a given district, cannot be made because the amount of phosphate available in the soil, the rate of reversion of applied phosphate, and the binding capacity of the soil must be taken into account. The determination of the quantity to apply must be made for particular soil types in each locality, and the grower should begin by following the best local practice.[2]

Supplementing barnyard manure with superphosphate has been found a valuable practice for soils deficient in phosphate. A combination treatment, consisting of moderate applications of

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[2] The general discussion of fertilizer practices, as given in Nebraska Agricultural Experiment Station Bulletin 365, Commercial Fertilizer for the Irrigated Sections of Western Nebraska, is applicable to other northern Great Plains districts.

manure along with moderate quantities of phosphate and nitrogen, has given profitable returns on many fields.

In an experiment conducted at Torrington, Wyo., in a field in which phosphate gave strong response, a combination of 6 tons of feed-lot manure and 150 pounds of phosphate an acre gave the best results. In this test, four types of plots were used: (1) Untreated; (2) treated with treble superphosphate (43 percent phosphorus pentoxide, P_2O_5) at the rate of 150 pounds an acre; (3) treated with feed-lot manure at the rates of 6, 12, 18, and 24 tons an acre; (4) one-half of each of the manured plots treated with phosphate at the rate of 150 pounds an acre.

The results, calculated as average acre yields, for the 2 years of the test were: Untreated plots, about 9 tons of sugar beet roots and 2,455 pounds of indicated available sugar; phosphated plots, 12.1 tons of roots and 3,621 pounds of sugar; manured plots (6 tons an acre), 13.4 tons of roots and 3,662 pounds of sugar; manured plus phosphate plots (6 tons manure, 150 pounds of phosphate), 15.4 tons of roots and 4,326 pounds of sugar. The average root yields from plots receiving 12 tons of manure an acre but no phosphate were about 1 ton less an acre than those from the plots receiving the combined treatment of 6 tons of manure and 150 pounds of phosphate. The acre yield of indicated available sugar was 130 pounds lower. In this test the maximum acre profit was obtained from the use of 6 tons of feed-lot manure an acre supplemented with 150 pounds of treble superphosphate. The use of manure, either alone or with phosphate, at rates of 12, 18, or 24 tons an acre did not increase yields enough to warrant the heavier manure applications.

SEEDBED PREPARATION

Preparation of the seedbed is expensive. It includes the mechanical operations of plowing, harrowing, disking, leveling, and occasionally spring-tooth harrowing and rolling. In addition to the mechanical operations to fit the soil for planting, the previous handling of a field—manuring, irrigation, drainage, and crop rotation—influences the type of seedbed obtained. Different soils require somewhat different treatment to obtain a good seedbed. Timeliness of the operations also affects the quality of seedbed obtained and the cost of preparation.

Maintenance of soil-moisture content is one of the very important factors to be considered in the preparation of seedbeds. A moist, firm, and deep seedbed is required. The soil must be worked to a fine texture, and the surface should be firm, smooth, level, and free from air pockets. A few clods about an inch in diameter on the surface of the soil will prevent wind movement of the surface soil, but larger clods are objectionable.

Growers who depend on moisture accumulated in the soil from winter rains must give special attention to firming of the seedbed and retention of soil moisture. Growers who irrigate to germinate seed are less concerned with these phases of seedbed preparation, as the effect of early irrigations is to compact the soil. A loose seedbed settles irregularly when irrigated, and this unevenness may interfere with uniform water distribution and

with seed germination. The packing of the seedbed is more difficult if the various operations of fitting the soil are carried on with dry soil.

If harrowing is put off until the entire field is plowed and if delays between harrowing, disking, and leveling are permitted, the surface soil will dry. Moisture is far better conserved when leveling and harrowing are done as one operation, or with intervals of less than 1 hour between, than when a day or two elapses between the two operations.

PLOWING

Plowing pulverizes the soil, incorporates crop residues and manures in the soil to a proper depth, kills weeds, and destroys weed seeds and insects. Plowing in the irrigated area is more often delayed by lack of moisture than by a surplus. Plowing when the fields are wet packs soils, except the very sandy types. Sandy soils are sometimes plowed when very wet to form clods in order to prevent blowing of the surface and to obtain a firm seedbed. Usually a moderate amount of moisture in the soil assists the farmer in doing a good plowing job. Harrowing immediately after plowing conserves moisture and pulverizes the soil much better than delayed harrowing (fig. 6). Sub-

Figure 6.—Plowing land for sugar beets.

soiling is not practiced in the irrigated area; it has been found beneficial only on a few lands that have hardpan very near the surface. The use of the two-way plow is common, as it eliminates dead furrows that interfere with irrigation.

Plowing is usually deep, 10 to 12 inches, for sugar beets. However, some growers now consider deep plowing necessary

only about one year in three. No extensive tests have been made upon which definite recommendations can be given as to the proper depth of plowing for sugar beets. Recent experiments indicate that when plowing is done immediately before planting, with not much time allowed for settling of the seedbed, shallow plowing is preferable to deep plowing. If equal yields can be obtained by plowing 6 or 7 inches deep instead of 10 or 11, the cost of growing the crop can be somewhat reduced, but this needs further testing.

Very few growers plant sugar beets on land that has not been plowed in the preparation of the seedbed, but occasionally plowing may be omitted. Very sandy soils are not benefited so much by plowing as are heavier soils. If the soil of a field from which sugar beets, potatoes, or beans were harvested is in very mellow condition the following spring, the field sometimes can be prepared for planting by disking or other types of surface preparation. It is possible that moisture is conserved to some extent by the omission of plowing, and the cost of producing the crop is somewhat reduced. Failure to plow under weed seeds often increases the labor required to remove weeds from the sugar beet crop.

Fall plowing is a generally desirable practice on irrigated land in the northern Great Plains. It aids in conserving moisture, especially on heavier soils where unroughened surfaces would allow winter rains and snows to run off or evaporate. Fall-plowed land is in shape for prompt and efficient fitting in the spring; hence, the sugar beet crop can be planted early. Fall plowing also mellows the soil. When sugar beets are to follow small grains, it is advisable to spread manure and plow the land during late summer or early fall. This practice destroys certain insects that live in soddy or weedy land.

There are some conditions, however, that may make fall plowing inadvisable. It may subject loose, sandy soils to serious wind damage during winter. Such crops as potatoes or sugar beets leave the land in a roughened condition after harvest, and fall plowing is not necessary for trapping winter moisture. As plowing can rarely be done in the northern Great Plains region during December, January, or February, growers ordinarily cannot both manure and plow land that has been occupied by late-harvested crops before freezing weather. The handling of manure supplies may thus influence the extent to which fall plowing is utilized. More manure is available for spreading early in the spring than in the fall. Growers frequently do not consider the benefit from fall plowing sufficient to make up for the greater difficulty in incorporating the manure in the soil. As an alternative to spreading manure in the spring, manures are sometimes left in feed lots over summer, but with some loss of manurial value. Although fall plowing is strongly recommended, conditions may warrant deferring plowing until spring.

PLOWING ALFALFA LAND

Alfalfa is a common crop in the irrigated areas, and some growers plant sugar beets immediately after plowing out alfalfa. This practice, however, is declining sharply. Plowing dormant

alfalfa in order to plant sugar beets in early spring is not practicable, as too many alfalfa plants survive and become weeds in the sugar beet field. Some growers crown the alfalfa, either in early fall or spring, by plowing about 4 inches deep. After the crowns are allowed to dry, the ground is again plowed to a depth of 8 to 10 inches. If the crowns are harrowed out on top of the ground, they usually die and few plants survive.

A more desirable practice when discontinuing the alfalfa crop is to avoid the double plowing by planting some crop other than sugar beets—commonly potatoes or corn—immediately after the alfalfa. Plowing is then done late in the spring to gain the benefit of a green-manure crop.

DISKING AND ROLLING

Disking land before it is plowed gives greater benefit than disking after plowing. When done after plowing, disking packs the subsurface of the plow slice to some extent, but it usually leaves too fine a mulch on the surface. Disking before plowing lessens labor in plowing and aids in incorporating manures in the soil. This is true of both barnyard and green manures. Pulverizing the top 2 to 4 inches of soil with a disk causes the plow slice to crumble, and fewer large clods are formed. As a much firmer seedbed can be formed by disking on most lands, disking before plowing is recommended on all lands except those that are very sandy. Subsurface packers are better than disks for packing plowed fields.

HARROWING

The spike-tooth harrow does some essential jobs in sugar beet seedbed preparation. A heavily weighted harrow should be run over the field within a few hours after plowing, to smooth it down and to prevent loss of moisture and formation of clods. The harrow should be used again as the last operation in seedbed preparation. After the ground is level and smooth and there are no small clods on top of it, the field must be harrowed to prevent wind erosion. If rain falls and crusts form, further harrowing is necessary to keep the field surface roughened.

LEVELING

Fields in the irrigated areas must be level, so that irrigation water may readily flow in the small irrigation furrows between sugar beet rows. They are therefore worked each year to maintain an even contour and to improve the contour. Box levels are used to smooth the land in irrigated areas. These implements are from 8 to 10 feet wide and from 16 to 24 or more feet long (fig. 7). They usually have three crosspieces that pick up soil in high places and deposit it in depressions. They are used to carry soil short distances and are effective only in correcting depressed or raised areas that are from a few inches to a few feet long and wide.

Some levels have an adjustable middle crosspiece and can be operated more in the manner of a fresno. They can be used to make major improvements in the surface of a field. They are heavy implements; they usually pack the surface of the soil

Figure 7.—Smoothing the land with a homemade drag immediately before planting sugar beets.

efficiently for planting sugar beets. They should be used when the soil is slightly moist, however, as they do not always pack the subsurface when the land is dry.

The leveling operation frequently completes the preparation of the seedbed for sugar beets, although a light harrowing is advisable as a final operation.

Some growers level the land once before plowing if the previous crop has left it uneven. Two levelings after plowing are common in preparation of the seedbed for sugar beets, the second being made across the direction of the first. Neither leveling should be directly in line with the rows of beets.

SEEDING

Any stand of sugar beets is directly affected by rate of seeding, depth of planting, viability of seed, planting date, and seedbed preparation. The desired rate of seeding and depth of seed placement are obtained by proper adjustment of the sugar beet drill. If a good initial stand is to be obtained, attention must be given to effective methods for crust breaking to foster emergence, should conditions so require. As soon as seedlings emerge far enough to make it possible to follow the drill rows, cultivation should begin.

At present all sugar beet seed planted in the United States is grown in this country. Formerly, it was imported from Europe. None is imported now, but some seed was exported during World

War II and immediately thereafter. The domestic sugar beet seed industry is of great benefit to sugar beet growers in the United States, as quality seed of the best adapted varieties is produced. The growing of sugar beet seed in the United States was developed by the Department of Agriculture in cooperation with the sugar beet industry.

SUGAR BEET SEED DRILLS

Several types of sugar beet seed drills are in widespread use in the irrigated districts. Some show an advantage over others under special conditions, but skill in operation and adjustment usually have more effect on the stand than the particular drill type. Drills with fertilizer attachments combine the operations of seed planting and fertilizer application, the fertilizer being placed in the furrow with or near the seed. This type of placement avoids fertilizer injury to the young seedlings if the fertilizers are principally phosphate compounds and the application rate is moderately low. Some special fertilizer attachments for sugar beet drills place the fertilizer beneath the seed, or in bands slightly to one side of the planted seed. As segmented, processed, or decorticated sugar beet seed came into use new drills were introduced. They have a plate or wheel type of feed and usually place the individual seed pieces in the drill row at regular intervals.

Both shoe and disk types of furrow openers are employed in the irrigated districts. Adjustment of the shoe attachments to give an even depth of planting is somewhat more difficult than with the banded-disk drills, but, when shoe attachments are carefully adjusted, satisfactory work is done. Shoe furrow openers do not operate so well as the disk types when the soil is wet, but do a better job on compacted soil. Old, worn attachments of either type do not operate well. The grower may select a drill equipped to fit his needs, as drills are furnished with either the shoe or disk type of furrow opener.

Sugar beet drills plant 4 or 6 rows at a time (fig. 8). As the cultivation equipment is pulled with the type of power used in planting, the cultivator and its set of tools must conform in number of rows handled to the number of rows that the drill plants.

After the seed drops into the trough made by the furrow opener, the soil closes in and the press wheels firm the soil over it. If the soil is dry, the pressure applied by the press wheels must be increased over what would be used with a slightly moist soil. If the soil is moist to wet, the pressure must be decreased. The adjustment of the pressure needs careful attention. Worn press wheels are often responsible for poor stands. A growing practice is to eliminate the press wheels and use short chains to drag in the soil over the seed. The whole matter of seed coverage is receiving attention, and some radical changes may be expected in planting devices to make and smooth the furrow, firm the seed into it, and then cover the seed with soil that is free from air pockets, yet not strongly compacted or smoothed over at the surface.

During World War II, in an attempt to reduce hand labor requirements for thinning sugar beets, and even to eliminate the necessity of hand thinning, the quantity of seed planted was reduced far below the usual rates. Furthermore, whole seed was, to a very large extent, replaced by sheared or segmented seed of which the planting units were mostly single germ. Usually 4 or 5 pounds an acre were recommended to give a sparse stand of seedlings, evenly dispersed along the drill row. Some farmers planted too small a quantity and others too large a quantity, thus defeating the purpose of the new procedure. Many stands were not so good as those formerly obtained and replanting was necessary. Even if stands were adequate, the fields had an uneven distribution of plants, but differential growth of the individual plants tended to compensate for this.

The trend now is back to whole seed, with a processing treatment to permit better grading and to rid the seed of the very large, multigerm seed balls. In common practice, seed balls that will pass over a $\frac{10}{64}$- or $\frac{12}{64}$-inch screen are removed and run through a special mill to shear or break them into 1-, 2-, or 3-germ units. Then the seed stock, consisting of seed balls $\frac{6}{64}$ to $\frac{10}{64}$ inch in diameter, together with the broken-up large seed balls, is rubbed in a polishing machine to give a graded product free from corky ridges and thus better suited for precision planting. Hence, present-day processed seed as supplied to farmers by beet sugar companies is mostly graded whole seed, except that large, multigerm seed balls are so treated that the final product for planting consists mostly of 1-, 2-, or 3-germ

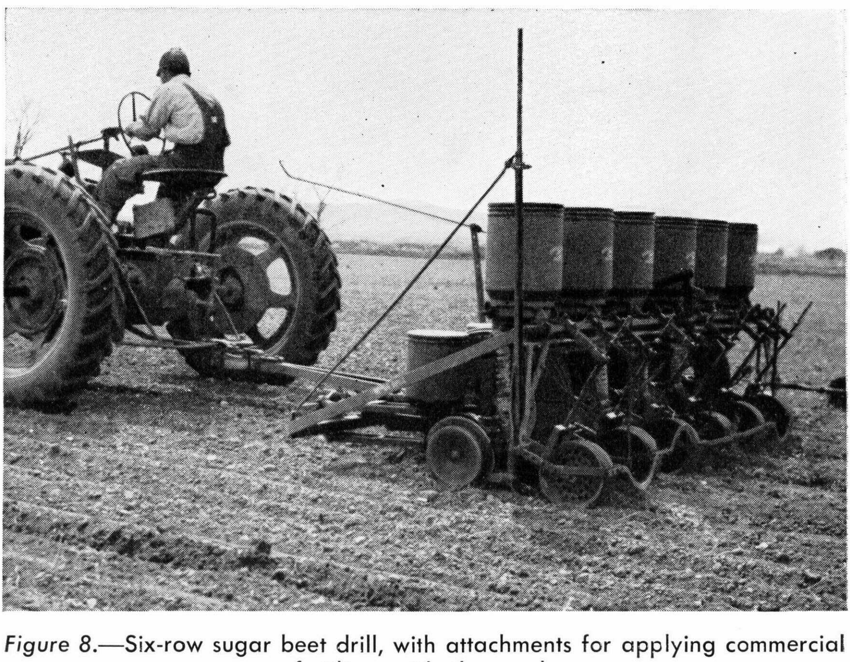

Figure 8.—Six-row sugar beet drill, with attachments for applying commercial fertilizer with the seed.

seed balls. The recommended planting rate of 5 to 7 pounds of processed seed takes into account the greater number of seed units to the pound and about corresponds to a 10- to 12-pound rate formerly used with American-grown whole seed.

In 4-year seeding-rate tests at the Scotts Bluff station, acre rates of 10, 15, 20, 25, and 30 pounds of whole sugar beet seed were compared in a series of replicated tests. The 20-pound rate gave best stands and yields. Sucrose percentages with the different seeding rates did not vary significantly. Use of 15 pounds of seed an acre produced yields only slightly lower than the 20-pound rate, and 10-pound plantings gave yields 1.2 tons lower. Planting more than 20 pounds an acre neither increased nor decreased the yield of roots significantly. These experiments were made with imported seed with a viability of about 70 percent.

Improvement in viability of commercial sugar beet seed has accompanied the change from imported to domestic seed. Domestic seed averages from 15 to 20 percent higher in germination than European seed. The quantity of whole seed necessary to obtain a good stand may be proportionately reduced when domestic seed is used. A seeding rate of 12 to 15 pounds for domestic whole seed corresponds to the 18- to 20-pound rate formerly recommended for imported seed.

The present trend toward low seeding rates to reduce the initial stands, and thereby reduce labor costs in thinning, may sometimes result in reduced acre yields. A compromise in seeding rates is to be expected, so that, on the one hand, overcrowded stands from heavy plantings, and, on the other hand, sparse stands, frequent during the war period, from sheared seed may be avoided. Attention is being turned to obtaining an even, but thin, distribution of plants along the drill row through better seedbed preparation, higher quality seed stock, precision planting, and, wherever possible, irrigating-up of the sugar beets.

DEPTH OF PLANTING

Very careful adjustment of the beet seed drill is necessary in order that the seed may be planted at the exact depth desired. Planting less than 1 inch deep is not practiced where rainfall is infrequent and the winds are drying, as the soil surface loses moisture rapidly. If the depth of planting is more than 2 inches, very few plants come up. Early in the season, or when the ground is moist, seed should be planted at the 1-inch depth. If conditions for germination are favorable, the plants will have stronger stems than those planted deeper and will emerge more rapidly from the ground. Later plantings should be made at 1½-inch depth.

In depth-of-planting tests at the Scotts Bluff station, at Torrington, Wyo., and at the Belle Fourche station, seed was planted at depths of 1, 1½, and 2 inches on nine different fields during seven different seasons. Yields from the plots with 1½-inch planting depths were much higher than those from plots with 1-inch or 2-inch planting depths. Very little difference in sucrose percentages or in purity coefficients was found. The average

acre yield of roots was 15.0 tons from the plots where seed was planted 1½ inches deep, 14.4 tons from seeds planted at a depth of 1 inch, and 13.8 tons from the plots where seed was planted 2 inches deep.

A common difficulty in sugar beet plantings comes from improperly prepared, loose seedbeds rather than from the seeding operation. Planting may have been made initially at the proper depth, but the press wheels make a depression along the drill furrow in loose soil, so that the surface of the row may be 1 inch or more below the field level. Winds or heavy rains deposit soil in this furrow. As a result, the seed is deeply covered or the young plants, as they emerge, become covered. More attention to seedbed preparation tends to eliminate this hazard. Rolling the soil after planting, where the press wheels have sunk so deep as to form furrows, is a poor substitute for proper seedbed preparation.

DATE OF PLANTING

Sugar beets should be planted as early in the growing season as the land can be prepared. The best planting dates are from March 20 to April 15. The hazards to the sugar beet crop that need to be considered are (1) lack of moisture for germination and continued growth and (2) frost damage to the young plants. Early-planted beets have a better chance of obtaining moisture and have about the same chance of surviving frosts as beets that are planted later. Experience indicates that in most years the early plants have grown to a size that enables them to withstand frost damage better than the smaller, later planted beets. Twenty years ago the common practice was to begin planting sugar beets April 15. Now, more than 75 percent of the crop is planted by that date.

In a series of experiments at Scottsbluff, Nebr., and Torrington, Wyo., from 1938 to 1945, the average acre yield of sugar beets from plots planted March 20 was 18.3 tons of roots; from plots planted April 1, 18.1 tons; April 10, 17.3 tons; April 20, 16.1 tons; and April 30, 14.2 tons. The difference in the sucrose content of the roots planted on the five dates was very slight, but the reduction in root yields brought about a decline in acre yields of sugar as planting dates were delayed.

SOIL-CRUST CONTROL

Dashing rains, followed by strong, drying winds, form heavy crusts, especially on the heavier soils, in April and May. Sugar beet stands are frequently severely injured by crusts that form on the soil at the time the seed is germinating. Heavy crusts are most frequently mentioned as the cause of injury to sugar beet stands, but severe injury has been brought about by very thin crusts. On sandy lands of high calcium-carbonate content a light rain frequently causes the formation of a cementlike crust about ¼ inch thick. The young plant, seeking to push up through the soil, hits the crusted soil and can emerge only by displacing a block or flake of soil.

Formerly harrowing was the most common method for breaking crusts on sugar beet fields. The present practice is to use

a beet cultivator, which does a better job for the following reasons: The tractors do not run on the drill row and the outline of the row remains visible; the furrows between the rows can be maintained so as to prevent blowing of the soil; and harrowing, especially late in the germination period, is objectionable because the harrow may cover or dig out plants so that part of the stand is lost in each harrowing.

The common cultivator tools are adequate for most fields, as the breaking of the crust between the rows causes sufficient cracking of the crust in the row to permit the sugar beet to continue growth (fig. 9). Finger weeders, spiked rollers, and other devices of several types have been made for breaking the crust on sugar beet fields, but their use is not widespread.

Operations performed to prevent crust formation are much more efficient than operations performed after the crust has formed. The common custom is to begin cultivation as soon as the field ceases to be muddy and the soil does not stick to the

Figure 9.—Unthinned sugar beets cultivated as soon as the drill rows can be followed. The ground is left rough and cloddy to minimize wind damage.

cultivating tools. The ground is often somewhat wet for tillage, but the dangers of wind damage or crust formation are much greater than those of the packing effects of wet tillage.

After the sugar beet seedlings are through the surface of the soil and a crust has formed around them, some growers attempt to break the crust to aid the young plants. Tests indicate that as much damage may be done to the crop in breaking the crust as would be done by the crust if it were left undisturbed. Repeated tests at the Scotts Bluff station indicate that the differences in

Figure 10.—Blocking sugar beets with short-handled hoe and hand thinning as one operation. Each laborer works two rows and should free the rows of weeds and leave the singled plants with the soil firmed around the roots.

yields are not sufficient to pay for the extra labor. Cultivation or harrowing of the sugar beets after a hard crust has formed shifts parts of the crust and kills many beets by shearing them off at the point where the crust loosens from the soil. The proper method is to cultivate before the heavy crust forms.

BLOCKING AND THINNING

Blocking and thinning consist of the removal of surplus plants from the sugar beet rows, so as to leave at proper intervals in the row single plants from which the crop is to be produced. As the young beet plants are singled weeds in the row are also removed. The work may be performed with equally good results as separate or as combined operations. Blocking and thinning an acre by hand require from 20 to 40 hours of labor, depending on the efficiency of the labor and the condition of the field. Rate of seeding and type of seed processing also are factors.

Thinning and blocking as a combined operation require less labor than blocking and thinning done separately. Short-handled hoes are used when the two operations are combined, and commonly two rows are thinned at the same time (fig. 10).

Sugar beets can be most efficiently thinned when the plants have from 4 to 8 leaves. Germination and growth of sugar beets are somewhat uneven, and in most fields plants differ consider-

ably in size. The practical conditions of growing the crop may require that some parts of the field be thinned before the planting has reached the 4-leaf stage, but thinning should not be begun on any field until most of the plants have 4 leaves. Plants in the 2-leaf stage are not well established; unfavorable conditions will kill many of them. On the other hand, delaying the thinning until the plants have 10 to 12 leaves usually reduces yields. Soil moisture and fertility are depleted to some extent by the delay in thinning. As the beets become larger removal of the excess plants is likely to injure the plants to be left. In tests conducted for a number of years in Nebraska, Wyoming, and South Dakota, gains in yields of about 1 ton an acre were obtained in plots thinned when the beets had 4 to 8 leaves, as compared with those in which the beets were thinned at either the 2-leaf or the 10- to 12-leaf stages.

It is important that thinners leave the largest and healthiest plants, not those that can be left most conveniently. Tests show

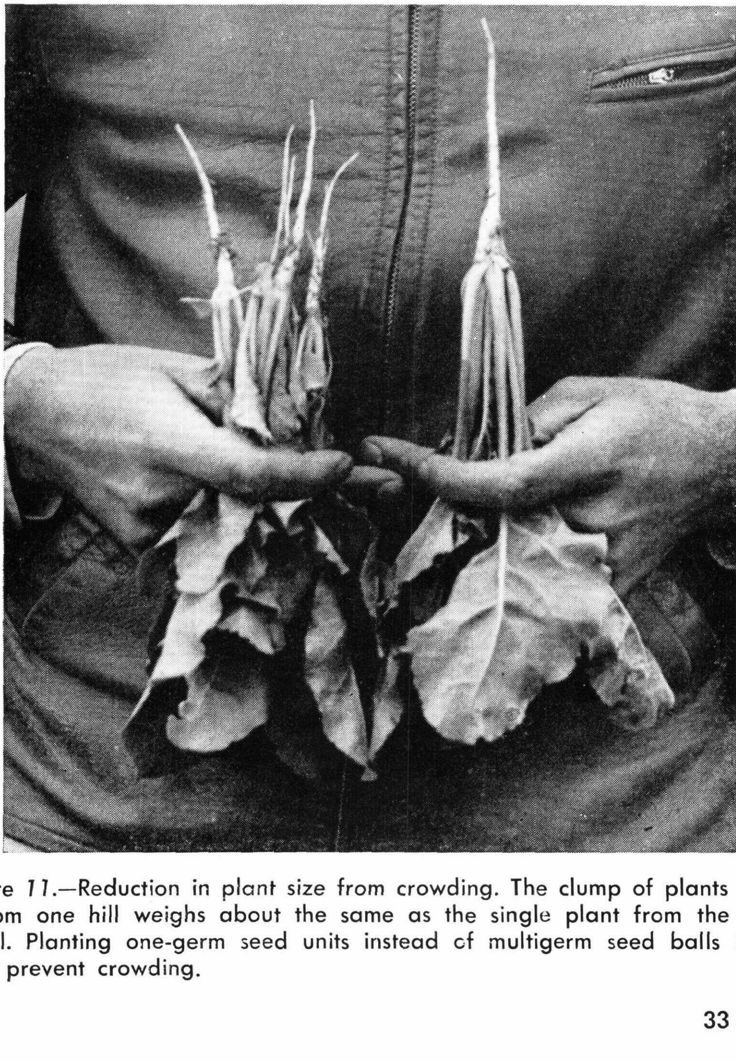

Figure 11.—Reduction in plant size from crowding. The clump of plants (left) from one hill weighs about the same as the single plant from the next hill. Planting one-germ seed units instead of multigerm seed balls helps to prevent crowding.

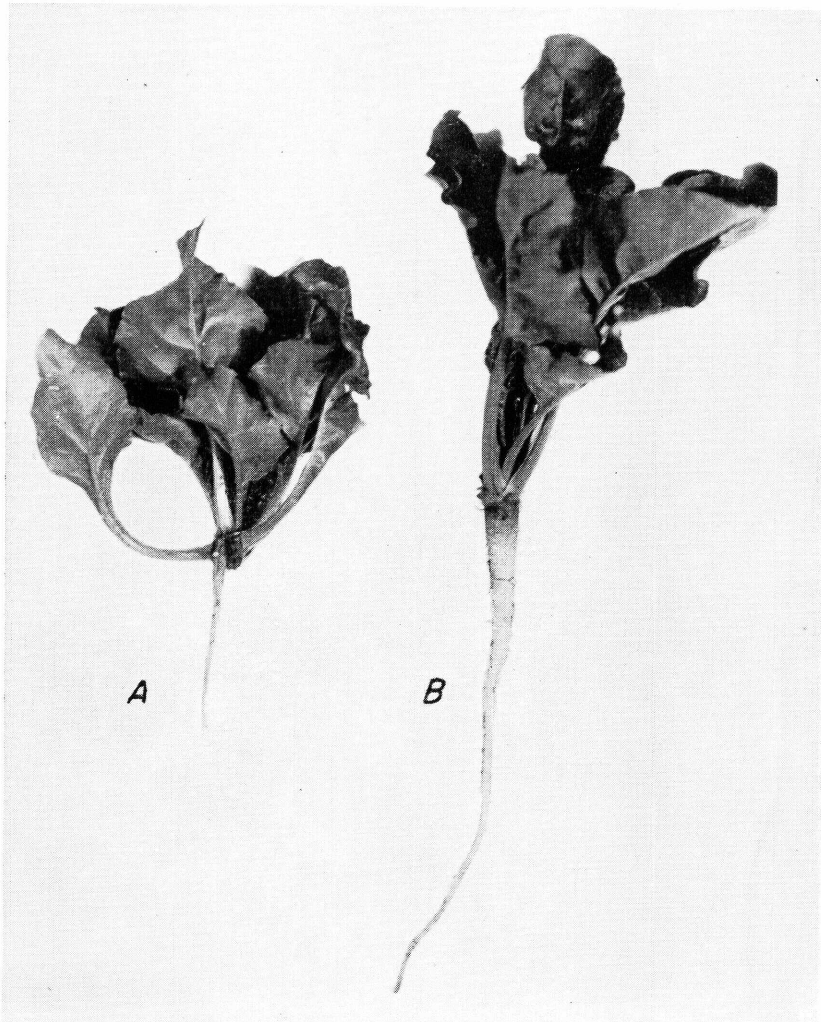

Figure 12.—A plant with a diseased root showing bowed petioles (*A*), in contrast to the upright growth of a healthy plant (*B*).

that when the largest beets are left at thinning time, the yield is greater than when medium-size seedlings are left. Leaving smaller beets seriously reduces the yield (fig. 11).

The aim in thinning is to leave sugar beet plants standing singly at as regular intervals as possible in the row. Care is necessary to prevent injury to the beets by removal of soil from the row. Experimental studies in several States have shown that 2-beet hills tend to yield about the same as nearby 1-beet hills, but the labor of topping 2 beets is greater than that of topping 1 beet. The extra costs involved in going over fields to remove doubles are not compensated for by increased yields.

The time of thinning is also influenced by the prevalence of damping-off, a seedling disease commonly called black root by

growers. Damping-off kills young plants, often seriously reducing the stand. The attack comes here and there along the drill row. When this disease is active in the field thinning must be delayed until affected and nonaffected plants can readily be detected and until the most seriously diseased plants die and disappear. Older seedlings that have diseased roots often develop thickened, bowed leaf petioles, in sharp contrast to the straight petioles of healthy plants (fig. 12).

Furthermore, the affected plants lag markedly in growth as compared with those that are unaffected. By selection at thinning time so that only large, sturdy plants are left, diseased plants may largely be avoided. The value of selecting the healthy beet should be stressed strongly. In experimental work at the Scotts Bluff station a large number of disease-affected plants, which were surviving at the 6-leaf stage and stood adjacent at proper spacing to healthy plants, were marked. Their growth in comparison with that of their healthy neighbors was followed through the season. Approximately one-third of the diseased plants died early, one-third produced rotted roots or roots too small to be of commercial value, and one-third produced marketable roots. A diseased plant left at thinning time apparently has limited chance of survival and represents more of a liability than an asset (fig. 13).

SPACING IN ROW

The standard distance between rows of beets is 20 inches, and the spacing between beets is 12 inches, which with a full stand gives 26,136 sugar beets an acre. Effort has been expended for several years to induce growers in some areas to grow the beets closer than 12 inches in the rows. Given soil fertility and water, there is some advantage from the closer planting. On the other hand, average yields from beets grown under different conditions and during several seasons indicate that the yield is not so greatly affected by spacing in the rows

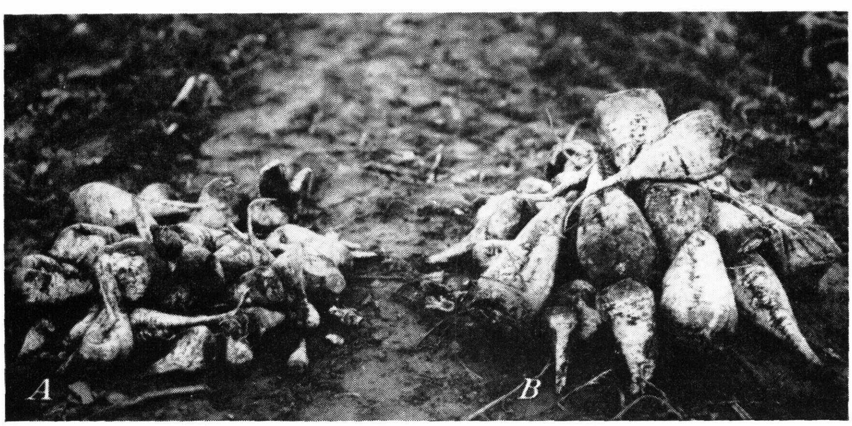

Figure 13.—A, Sugar beet roots grown from plants that were noted in the spring to have partially recovered from black root; *B,* roots produced by plants that were classified as healthy.

when the range is within 8 and 16 inches as by other factors. Work required for thinning and topping decreases with the larger row spacings; therefore, small losses where beets are spaced slightly wider in the row may sometimes be absorbed by other savings. Uniformity of stand is more important than actual spacing in the row, and more is to be gained by attention to uniformity of stand than to any particular pattern of spacing.

In 5 tests in Nebraska, Wyoming, and South Dakota, beet-row spacings of 6, 9, 12, 15, and 18 inches were compared. The plants spaced 6 inches apart produced, as an average, 16.62 tons of roots an acre, with a sucrose percentage of 15.25; those spaced 18 inches apart produced 16.70 tons of roots an acre, with a sucrose percentage of 14.80. In 5 other tests, the sugar beets were spaced, respectively, 8, 10, 12, 14, and 16 inches apart in the rows. About 15.5 tons of roots an acre were produced from the 8-, 12-, 14-, and 16-inch spacings, as against 15.4 tons from the 10-inch spacing, not a significant difference. The sucrose percentage of the beets from the 8- and 10-inch spacings was approximately 17.3; from the 12- and 14-inch spacings, 17.1; and from the 16-inch spacing, 17.0. Results of the 10 tests indicate that closer spacing may increase sucrose percentages very slightly but has little effect on acre yield of roots.

MECHANICAL BLOCKING AND CROSS-CULTIVATION

Reduction of the initial stand by mechanical blocking, especially cross-blocking, has been used less widely in the northern Great Plains than in the humid or intermountain areas. Despite savings of hand labor amounting to 25 to 40 percent over that required for blocking and thinning by hand, the practice of cross-cultivation did not greatly increase after its introduction about 20 years ago. Growers usually limited its application to emergencies brought about by weather or by scarcity of hand labor that so delayed field work that the sugar beets became large and the fields weedy. An objection to cross-blocking in the irrigated districts has been the breaking down of irrigation furrows by the cultivating tools. Without careful work, small plants may be covered with soil. If the initial stand had many skips in the rows, the stand left by the cross-blocking was likely to be inferior to that which could be left by experienced hand labor.

Mechanical blocking usually can be done satisfactorily with beet cultivators properly equipped with knives or sweeps. The cultivator should have markers similar to those on a beet planter. Weeder knives or sweeps of suitable length and low pitch are set along the tool bar of the cultivator, together with cultivator disks, so that as the cultivator traverses the field at right angles to the rows a cut of several inches is made and a narrow block of plants is left. Thus, for a 55 percent stand to leave 100 beets to each 100 feet, 7-inch sweeps are set on 10-inch centers along the tool bar. These cut out 7 inches and leave a block of 3 inches from which the thinners are to remove excess beets. With better stands, a 7-inch cut and 2-inch block may be selected. If knives of a different type are used, as, for

example, a nearly flat duckfoot knife, the arrangement of the tools on the tool bar may be such that a 5-inch cut is made and a 2- or 3-inch block left, depending on the stand. If initial stands are relatively thin and consist of uniformly distributed seedlings and it is desired to reduce the thinning job as much as possible, or to omit it, a block width of about 1½ inches may be left, with cuts of 7 or 8 inches.

Cross-blocking or other form of mechanical stand reduction should be considered as a labor-saving practice; it should not be expected to increase yields. The improved weed control and the timeliness of the blocking and thinning operations derived from a relatively rapid machine operation may prove advantageous.

Farmers' Bulletin 1933, Sugar Beet Blocking by Machinery, gives details of the operation.

Down-the-row blocking devices are now being used to a greater extent than cross-blockers. They have the advantage of not breaking down irrigation furrows, and many have a more satisfactory range of adjustment than cross-blockers. Beet sugar companies in the area suggest the use of improved types of down-the-row blockers, especially when processed seed is precision-planted to give thin, evenly distributed sugar beet stands consisting largely of one or two plants in a place. Frequently the fields may require only trimming with hoe, finger-thinning being omitted. As much as 25 percent of the acreage in some districts was blocked in this way in 1950, and with excellent results.

HOEING

Sugar beet fields should be, and usually are, kept free of weeds. Weeds close to the plants are hoed or pulled out. At the first hoeing operation, most weeds are cut out with the hand hoe. Later in the season tall weeds are pulled. The labor involved in hoeing depends on the cultivation job done prior to thinning, on the kind of thinning job done, and on the efficiency of the subsequent cultivations. Very early thinning is sometimes responsible for increased labor of hoeing, because more small weeds survive than ordinarily are left when larger beets are finger-thinned.

Some growers want hills having doubles to be thinned at the time of first hoeing, but this will not increase the yield. Doubles should not be left at thinning time, but if they have been left it is not worth while to expend labor during hoeings to remove them.

The hoeing job can be greatly reduced by use of tractor-drawn cultivating machines—pencil, finger, or bean weeders—at the time the beets have 8 to 10 leaves (fig. 14). They are drawn both along and across the rows. The springy, pliable tines of the weeder pull out fibrous-rooted weeds, leaving the deep-rooted sugar beets uninjured. Contract rates for hoeing may have obscured the situation and caused growers to overlook the advantages to be gained from mechanical weeding.

CULTIVATION

The principal purpose of cultivation is to kill weeds. Other benefits, such as improvement of the condition of the soil by loosening, promotion of aeration, and conservation of moisture, seem to be of relatively minor importance in the irrigated districts.

Although weeds start in the fields about the time the beets germinate, May 1 to June 15 is usually the important period for weed control. The average field of sugar beets requires not less than two cultivations—one before and one after thinning—primarily for weed control. If the two cultivations and the thinning are carefully done, the weed problem for most fields is solved.

Excessive cultivation of sugar beets is as harmful as insufficient cultivation. Every cultivation adds something to the cost

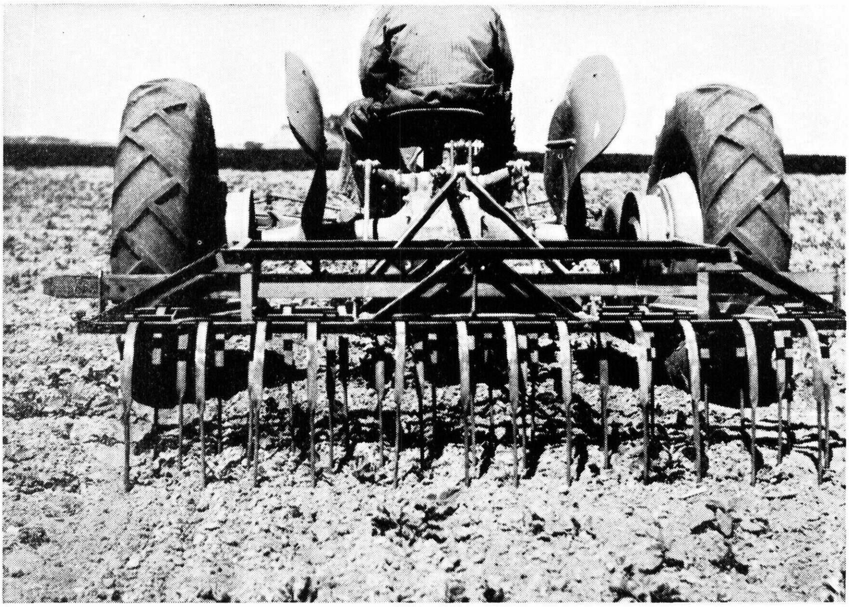

Figure 14.—Weeding unthinned sugar beets with a bean or pencil weeder. When the implement is pulled across the rows its flexible tines remove fibrous-rooted weeds without damaging the sugar beet stand. Photograph by Beet Sugar Development Foundation.)

of growing the crop and usually destroys some of the plants, especially when they are small and may be covered by dirt. In normal seasons one cultivation before thinning and one after thinning, followed by ditching for irrigation, are sufficient. On lands that are difficult to irrigate, a second furrowing is necessary after the first irrigation.

In 4-year tests at Belle Fourche, S. Dak., no better yields were obtained from four, five, six, or seven cultivations than from three cultivations. With no cultivation, or only one or two cultivations, the yields were as good, but hoeing operations for weed control cost

more. Additional cultivations to prevent wind damage may be needed in seasons when rainfall is frequent and crusts are formed.

Sugar beets should receive shallow cultivation. Deep cultivation ($1\frac{1}{2}$ to 2 inches) may not harm the beets early in the season unless it is very close to the drill rows. By the time the leaves have spread to cover the rows, the roots extend beyond the drill row and deep cultivation is harmful. The sugar beet plant gets about two-thirds of its moisture from the top foot of soil and only one-third from lower depths, which explains why great damage to the crop can be done by frequent or deep cultivations.

In tests in South Dakota, the average yield of shallow-cultivated fields was 0.8 ton an acre greater than was obtained from fields subjected to deep cultivations.

IRRIGATION

Several factors involving irrigation of the crop are important in selecting land for sugar beet growing. A good supply of water must be available at all times during the beet-growing season. The land must have sufficient slope so that the water will run slowly in the narrow furrows between the rows. Land having a pronounced slope allows the water to run off rapidly, making proper wetting of the soil difficult. Good drainage, so that excess water will not accumulate on any part of the field, is essential. Fields with a high water-holding capacity require less frequent irrigations and are considered more desirable for sugar beets. All beet fields need good subsurface drainage.

NUMBER OF IRRIGATIONS

The average field of sugar beets requires from three to seven irrigations each season. The irrigations supplement rainfall that comes during the growing period. There is, therefore, considerable variation in the number of irrigations required during different seasons. Transpiration, or loss of water, from sugar beet leaves is largely determined by the temperature. A field of beets frequently uses from three to five times as much water a day during a hot, dry period as during periods of high humidity and low temperatures. The type of soil and the amount of water it will hold also determine the number of irrigations needed. Beet fields that have a high water table or that are too rough for even distribution of the water may be damaged by too much irrigation water, but more fields are permitted to suffer from lack of irrigation than are damaged by overirrigation. Overirrigation wastes water, but it does not reduce yields of beets on the average field.

IRRIGATION METHODS

The common irrigation practice is to furrow-irrigate, not to flood-irrigate. Small streams of water are run in the furrows, thus preventing breaks from one furrow to another. The supply laterals should be sufficiently close to make unnecessary an excessive head of water at the upper end of the row in order to make the water reach the lower end of the field. Too long a

Figure 15.—Plastic tubes used for distribution of water to the furrows between sugar beet rows. The tubes siphon water from the lateral ditch to the furrow. (Photograph by Beet Sugar Development Foundation.)

furrow wastes much water. Water in a deep furrow normally runs twice the distance in the first hour of run as in the following hour. Therefore, with due consideration of the rate at which the water penetrates the soil, the row to be irrigated should be of a length that permits an ample irrigation without the use of an excessive amount of water. Water which penetrates too deeply into the soil is largely lost so far as the plant is concerned.

The introduction of plastic tubes for the distribution of water between the sugar beet rows has greatly reduced the cost of irrigating and can be a means of conserving much water that was formerly wasted. The average irrigator can handle not more than 75 furrows of water at a time in a sugar beet field on normal land without the use of plastic tubes. With plastic tubes, however, twice this number of furrows can be handled. Night irrigation of sugar beets is very difficult without this special device for distributing water in the proper amount to each furrow (figs. 15 and 16).

The method of fitting fields for irrigation has improved greatly. Land-leveling machines are now used to make the slope of a field more uniform, resulting in more efficient distribution of water and reduction in labor requirements for irrigating. Increased use of cement linings for ditches is cutting down the loss of water in laterals and is speeding delivery of water to the fields.

TIME OF IRRIGATION

Keeping the top foot of soil moist—the chief objective in irrigation of sugar beets—requires frequent light irrigations.

Excessive amounts of water carry the soluble plant foods out of the soil or to depths from which they are not readily recovered.

Beet roots normally extend laterally about 3 feet in each direction from the base of the plant, and as the distance from the plant increases, or as the depth increases, the concentration of roots becomes less dense. There is no need to wet more than the top 2 feet of soil during irrigation, and the average soil will not hold more than 6 acre-inches of water in this soil layer. The sugar beet obtains approximately 65 percent of its water from the top foot of soil and 85 percent from the top 2 feet. Natural storage of water in the soil and deeper penetration of excess water usually provide sufficient moisture in the area below 2 feet.

Normal rainfall may provide sufficient moisture for germination of the seed, but irrigation is needed in many years. In order that irrigation water may be applied to germinate the seed, it is most desirable to make irrigation furrows at the time of planting between alternate sugar beet rows. Application of water within 24 hours after planting is advisable. Uneven stands are common where irrigation is delayed, as some of the seed may be in soil moist enough to sprout it and the rest may remain ungerminated. Flooding for germination often causes formation of a hard crust. Sandy lands that subirrigate slowly are very difficult to irrigate without flooding.

Irrigation of the young plants normally begins from June 20 to July 5, with subsequent irrigations at intervals of 10 days to 2 weeks. The final irrigation is ordinarily not given later than September 15. The frequency of irrigation depends on

Figure 16.—Upper part of a sugar beet field that has been evenly and rapidly irrigated. (Photograph by Beet Sugar Development Foundation.)

many factors and is a problem of individual fields and individual seasons.

Condition of the soil—not the stage of plant growth—determines when irrigations should begin. In the early period of sugar beet culture in the irrigated districts many growers believed that irrigating at the beginning of the season kept the roots from growing deep in the soil and caused side branches to form. This has not been found true. The sugar beet root is normally long and tapering; branching of the main root may be caused by a high water table, loose seedbed, and insect or disease injuries, or by other conditions. In places in the sugar beet field where straw or haystack bottoms were plowed under, there are often many sugar beet plants whose roots are branched and sprangled.

The first irrigation should be given when the soil begins to lose its friable, moist feel; and this guide should be followed throughout the season. Leaves that turn dark green or fail to recover from midday wilting are a sign that water is needed and irrigation should be given.

The last irrigation of the season should be late enough to assure continued growth until frost kills the leaves and to provide enough moisture in the soil for easy lifting of the crop. The usual time for this application is about 2 weeks before the customary harvest date—not a full month.

If the supply is limited, irrigation water is best applied before the beets are seriously damaged by drought, rather than saved for later use. Intervals between irrigations may be slightly lengthened when the water supply is short.

Tests at Belle Fourche, S. Dak., over a period of 4 years, on the effects of beginning irrigation about June 20 in comparison with delaying applications until July 1 or July 10, showed that, in general, if less than 1 inch of rain fell from June 20 to July 1, the delay in irrigation reduced the acre yield of roots, as an average, 1 ton; when at least 1 inch of rain fell in this period, there was no loss of tonnage. Sucrose percentages were similar with all dates of irrigation. Delay in irrigation after July 1 almost always brought about a loss in yield.

Where the beet root aphid seriously infests sugar beets, it has been discovered that the winged migrants of this insect usually come to the beet fields during the last week of June. If the soil has been recently irrigated at this date, the infestation of roots is much reduced.

The average irrigation of beets uses from 3 to 6 acre-inches of water, including runoff. An acre-inch of water is a definite volume; it does not imply depth of penetration, which is determined by the permeability of the soil and other factors. In irrigating for the germination of the seed, the land is usually loose and absorbs a large amount of water. Irrigation of alternate rows is usually adequate for germination of seed or for the young plants before thinning. Because the zone of root distribution is relatively shallow, it is not necessary to wet more than the top foot of soil early in the season. At any stage of growth the sugar beet has more feeding rootlets in the

top foot of soil than in the lower feeding areas. It does, however, have roots penetrating as deep as 6 feet below the surface.

HARVEST

Harvest operations include lifting, topping, loading, hauling, and delivery of beets to the receiving station. Many of the operations, as well as time of harvest, affect the weight and sucrose percentage of the beets.

Before harvest, preliminary tests of quality are usually made by field men of the beet sugar company, who sample fields throughout their districts. When enough fields have reached acceptable quality, the purchasing company announces its readiness to receive the crop. This normally is the first or second week in October.

A few years ago harvest generally began the last week in September, but it was found that the beets could make considerable growth during this week and in the early part of October. Improved roads and improved equipment—especially trucks, mechanical harvesters, and loaders—have speeded up the process of taking beets from the ground and to the receiving station and have helped growers take advantage of a later harvest, when roots have reached maximum size and sucrose content.

As the northern Great Plains are subject to early winter freezes, growers cannot delay harvest for more than a few weeks.

Mechanical harvesting and other applications of power to farming operations are having profound effects on the methods of sugar beet culture. In many States the harvesting of beets on large acreages is done almost wholly by machines. In the northern Great Plains area at least one-half of the 1950 crop was harvested by machine. In many districts hand-harvested beets were loaded with one or another of the pickup devices that elevate the topped roots from the windrows into trucks.

Sugar beet harvesting machines, although well past the experimental stage, are still undergoing development. Because of the range in field size, as well as in soil and crop condition, no one type of harvester can be singled out as capable of doing an entirely acceptable job or as the outstanding choice for a district. The improvements made from 1945 to 1950 have been very important; similar advances are to be expected in the next 5-year period.

Some sugar beet harvesters are of the combine type, performing several operations as the machine passes down the row. One type of combine may top the beets in the row and then lift; other types may lift the beets first and then cut off the tops with disks or chisels. Both types make provision to conserve and windrow the tops. The topped beets fall on elevating mechanisms for loading into a truck, or they may be windrowed (figs. 17 and 18).

Some harvesting equipment used in United States consists of separate tractor-drawn machines operating singly or hitched

together. One machine cuts off the tops as it passes down the row and elevates the tops into a truck or windrows them. The second unit lifts the roots and either elevates them into a truck or piles them. A system coming into use on small acreages in

Figure 17.—Mechanical harvesting of sugar beets: *A,* The harvester tops the sugar beets as they stand in the ground and windrows the tops, after which the plowshares lift the roots and discharge them onto a carrier to be either windrowed or elevated into a truck; *B,* pick-up loader elevates the sugar beet roots from the windrow to the truck for hauling to the receiving station of the beet sugar factory. (Photograph by Beet Sugar Development Foundation.)

Europe employs small machines either horse- or tractor-drawn. The beets are topped as one operation, and the tops are moved to one side or are loaded on a truck. Then the roots are lifted, rotated in a drumlike cage to remove dirt, and finally discharged

in a pile, or they are elevated to a trailer, which, when full, is drawn to a truck and emptied.

Still another system is used in northern Idaho and eastern Oregon, where the tops are not conserved for cattle feed. A machine known as a beater-topper, equipped with leather or rubber flails, is drawn down the field and the foliage is whipped from the beet roots as they stand in the row. The roots are left with crowns intact for subsequent lifting. Usually a knife is placed on the lifter to scalp the beets, thereby removing the terminal bud and immediately adjacent tissue. The leaf blades and petioles are beaten into pieces and discharged on the soil.

As harvesting by machine becomes more and more the accepted practice, methods of culture, type of beet grown, width

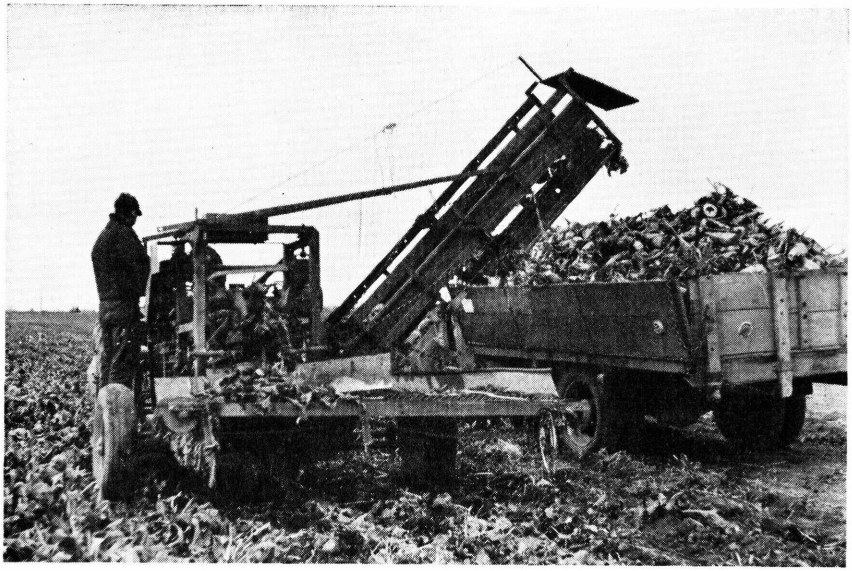

Figure 18.—Mechanical harvesting of sugar beets. This harvester lifts the plants, which are then clasped by the tops and carried to the topping mechanism; the roots, after being topped, are elevated into a truck, and the tops are discharged in a windrow at one side. (Photograph by Beet Sugar Development Foundation.)

of rows, weed control, and many other phases of beet growing will be better adapted to fit the sugar beet to the mechanized program.

When the crop development justifies, early harvest has certain advantages. Both laborers and machines are usually able to perform their tasks better when the sugar beet tops have not been injured by frost. Lifting the roots is often less difficult early in the season because the soil is more moist. Snow sometimes falls during the late harvesting periods in the irrigated area, and if it is deep the loss of sugar beets from covering may become a considerable item. Lifting of beets may be interfered with late in the season because of freezing of the soil.

Also early harvesting gives time for fall plowing and land preparation for the succeeding crop.

If sugar beets are in active growth during the early part of October, deferring their lifting and topping until reasonably late in the harvest season has a definite advantage over early harvest. Normal temperatures for late September and early October are, during many years, favorable for increasing both root weight and sucrose percentage of sugar beets. Increase in weight of roots continues until the foliage has been killed by a severe frost. A series of samplings from a field at the Scotts Bluff Field Station, during a season when no killing freeze occurred until November 1, showed for the month of October an increase in sucrose percentage by 0.1 a day. Sugar company daily records of the sucrose percentage of beets sliced, so far as the records deal with roots delivered directly from the field and not with stored roots, indicate a somewhat similar general increase in the factory average for sucrose percentage until a killing freeze.

Except as special conditions, such as rotting of roots or strong regrowth of tops following either leaf spot defoliation or early freezing, make an early harvest desirable, the grower should generally defer or proceed slowly with harvesting until fairly late in the season. Then the harvest should be completed as rapidly as facilities will permit.

LIFTING

Proper adjustment of the lifting mechanism of the sugar beet harvester is very important. This applies not only to the puller points, or plowshares, of the ordinary 1-row team- or tractor-drawn beet lifter or puller, but also to the equivalent tools of the newer forms of mechanical harvesters. If the beets are to be topped by hand, lifting is accomplished by two narrow-bladed plowshares that are drawn down the row at a depth of 8 to 10 inches below the surface. The frame holding the plowshares straddles the row. Depth, width between shares, and the attachment of the hitch are important factors in the job of loosening and slightly raising the sugar beet roots.

Lifting equipment that is improperly adjusted or has worn parts, especially worn or blunted puller points, does not do a satisfactory job: it either leaves roots in the row without loosening them or breaks off the lower parts of the roots. Lifters that move the beets sideways or bunch them along the row cause many to be covered and lost; they also destroy many leaves that are valuable for stock feed. Very hard, dry ground makes the entire lifting operation extremely difficult and increases the number of broken beets. The last irrigation should be timed for about 2 weeks before the harvesting date, so the soil may be fairly moist. Losses of sugar beets from carelessness in lifting may amount to as much as a ton of roots an acre.

Mechanical harvesters have introduced many new problems with respect to adjustment of points, depth, and hitch that will make it possible to do the job of lifting without skipping beets and without excessive breakage of roots. Each machine poses its own problem. In addition, the condition of the soil is very im-

portant. The sugar beet grower must seek by proper methods of culture, including weed control and soil management, together with proper timing of irrigations, to promote the efficient operation of the harvester.

TOPPING

Present contracts between growers and the sugar beet factory require that sugar beet roots be topped so that the leaves and crowns are removed from the roots at the base of the lowest leaf scar (fig. 19).

Usually it is specified that roots under 4 inches in diameter must be cut at right angles to the long axis, whereas roots over

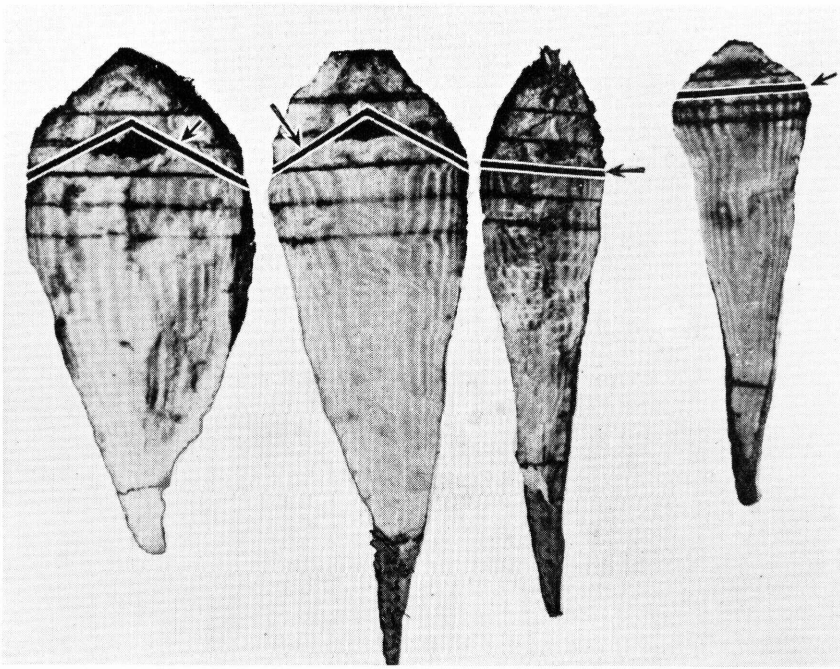

Figure 19.—Large, medium, and small sugar beet roots marked to show different types of topping. The heavy lines indicate the type of topping usually prescribed in the contract.

4 inches in diameter may be cut at an acute angle to the long axis of the beet, leaving the crown part as a low cone. This provision for large roots permits leaving a part of the crown on the root; however, all leaves and outer parts of the crown that bear leaf scars must be removed. Several strokes are required to top a large beet by this method. Topping lower than the market requirement decreases the tonnage; topping higher is useless, as the grower receives no payment for the additional crown left on the beet and also loses this valuable stock food.

The standards for sugar beets that are hand topped apply also to those mechanically topped, the crown parts left on the

root being charged as tare. With the introduction of mechanical beet harvesters, there has been a speeding-up of the rate of harvest, but a decrease in quality of topping. It is expected that the machines will be improved so as to do a better job and also to accomplish better salvage of the sugar beet crowns and tops.

DELIVERY

Sugar beets are usually hauled to the weighing station the day they are topped. Formerly, it was not uncommon to see roots lying in windrows or in piles in the field for a day or longer after they were topped. The increased use of loaders in the field and of trucks to haul the roots has enabled growers to make deliveries more promptly. This is a decided advantage because beets that have been left overnight in the fields are often noticeably damaged by either drying out or freezing. Beet sugar factories commonly store a large part of the crop in piles for 30 to 60 days before slicing. Frozen or withered beets do not keep well in storage, and processors now demand that only fresh beets be delivered. It is to the grower's advantage that no frozen beets be delivered to the beet sugar factory, as the price paid for beets is in proportion to the amount of sugar made from them. The factory seeks to process without delay any loads that have been damaged after topping.

Overloading of trucks can cause losses of sugar beets to the farmer. Because the trucks delivering beets travel at high speed, many beets fall off on curves or where the roads are rough. This is not a trifling item; at the height of the hauling season several tons of beets a day can frequently be picked up along a highway. As hauling usually is done by contract, this waste is preventable by attention on the part of the grower and his contractor.

SUCROSE PERCENTAGE

By the first of September, in the irrigated districts of the northern Great Plains, the sugar beet has attained maximum spread of leaves, has formed a taproot of moderate size, and has developed a wide expansion of its root system. When this stage is reached the plant is in condition to accumulate sugar rapidly. The sugar beet contains a relatively high percentage of sucrose in its roots during the entire growing season, usually far more than other plants. Analyses in July and August frequently show sucrose contents ranging from 8 to 11 percent; those made about September may show 12 percent. In late October, the sucrose percentage commonly ranges from 15 to 18 or higher. Fall temperatures—especially those of October and November—exert a strong influence on the quantity of sugar stored during the growing period. Cool fall weather promotes sugar storage, and years of high sucrose percentages are those in which late September, October, and November have been prevailingly cool. Growers have noticed that late rains or heavy irrigations tend to lower sucrose percentages—a depression caused, in part at least, by increased intake of water, which

increases root weight and correspondingly dilutes the stored substance.

That chlorophyll, the green coloring matter in leaves of plants, manufactures sugars and other carbohydrates is common knowledge. The practical aspects of this, however, are often overlooked, especially the functioning of the leaves and the need for conserving a full spread of foliage. The important work of leaves is brought to the fore when the effects of injury to them are assessed. If the foliage is injured, as, for example, by leaf spot, sugar manufacture is lessened proportionally, storage of sugar is reduced, and the foliage replacement that promptly starts draws heavily upon carbohydrate reserves in the root.

Reduction of sucrose percentages from severe leaf spot injury by as much as 2 percentage units has been observed. Unless the season is exceptionally prolonged, the loss in sucrose percentage due to leaf spot attack is seldom made up in the subsequent growth of the plants. In periods of severe and early fall frosts all or a large part of the leaves may be killed. If warm weather follows such frost injury, leaf growth may be stimulated and sucrose percentages will decline sharply. Beets upon which the leaves have been killed do not increase in root weight during the period of formation of new leaves; hence, there is no compensating factor for the effect on quality.

Variation in the sucrose percentage of individual beets may be due to many factors, including soil differences, heredity, and climate. In other words, the hereditary endowment of the plant and the conditions to which it is exposed are reflected in the quality of the root produced. By plant-breeding methods extending over a century, the sugar beet has been bred so that it normally is capable of producing a root in which a very high percentage (15 to 20 or more) of its weight is sugar. The varieties used are chiefly the product of mass selection, and the individual plants vary greatly, the average performance of any commercially acceptable brand or variety being high, other conditions being favorable. Growing conditions from year to year, especially climate, are influential in producing variations in sucrose percentages.

When beet sugar factories buy sugar beets on the basis of both weight and sucrose percentage ("test"), the spread in the sucrose percentages reported for the various load samples often puzzles growers. This spread is the result of individual differences among plants and of widely varying growth conditions within the field.

In the present system of determining sucrose percentages, only a small sample is taken from a load; hence, the sucrose percentage found may differ from that obtained from another load. When the percentages are averaged, a close approximation of sucrose percentage for the whole delivery is obtained. Furthermore, delivery of sugar beets extends over a period of 2 to 4 weeks for large fields. During this time, the quality of the beets may change. High or low values, attributable to sampling, tend to counterbalance each other.

The nature of the problem and the variability of weights and

of sucrose percentages are illustrated by the following results from analyses made under as close control as possible.

Ten beets were selected at random from a field where the beets were grown so widely spaced as to be free from competition, to give some idea of the weight differences that may exist among individual beets. The weights in pounds were: 2, 2.2, 2.8, 1.2, 6.5, 0.9, 1.2, 4.1, 6.1, and 2.3. The sucrose percentages, taking the roots in the same order, were: 12.6, 15.6, 14.0, 14.5, 12.1, 12.9, 13.2, 13.1, 12.5, and 16.6.

Other roots, grown under conditions of normal competition in a commercial field and standing adjacent to one another in the row, were selected at random. The weights in pounds were: 1.5, 3.0, 3.3, 4.3, 2.1, 3.0, 2.7, 2.1, 2.8, and 3.3. The sucrose percentages, taking the beets in the same order, were: 18.7, 17.5, 13.3, 14.6, 12.1, 15.7, 13.8, 16.6, 17.5, and 14.8.

The range shown in these analyses, one set representing plants grown so widely spaced that the effect of adjacent plants was avoided and the other under normal field competition, is sufficient to convey a general idea of the variations between individual beets as to both weight and sucrose percentage, even when the individuals compared have been grown under similar conditions. As the number of beets, or the number of samples, increases, the average values obtained become increasingly dependable when applied to the whole lot under consideration. Differences between small individual samples cannot be avoided.

SUGAR BEET BYPRODUCTS

Byproducts from the sugar beet crop are beet tops, which are left on the farm and used for stock feeding, and beet pulp and beet molasses, which are factory byproducts. The high feeding value of sugar beet byproducts is the basis of an extensive feeding industry in the irrigated areas. Part of the value of the sugar beet crop to the farmer is its byproducts, and the livestock industry that is fostered has very significant effects on maintenance of soil fertility.

SUGAR BEET TOPS

The leaves and the part of the crown cut from the sugar beet in harvesting are included under the designation beet tops. The weight of tops from an average acre of sugar beets varies from 40 to 75 percent or more of the root weight. Yields of tops vary in different fields because of such factors as disease or insect attack, maturity of tops at the time of harvest, and soil or growing conditions that have affected the ratio of root to top weight.

The feeding value of beet tops can conveniently be given in terms of cured tops. Beets are harvested late in the autumn, and the tops do not cure to so dry a state as hay. Moisture contents usually run about 30 percent. The weight of cured tops obtained from the average field may be roughly calculated as one-sixth of the weight of the roots. Thus, a crop yielding 12 tons of roots an acre produces approximately 2 tons of cured beet tops. Losses of leaves from poor methods of harvesting or

curing are not taken into account in this figure. Many growers waste 25 percent or more of the weight of tops through failure to recover them from the field.

Two tons of cured tops, estimated as the yield from the average acre, contain approximately 1,800 pounds of digestible nutrients, in contrast to 2,000 pounds of digestible nutrients in 2 tons of alfalfa hay. Hence, it is often said that a ton of cured tops is nearly equal in feed value to a ton of alfalfa. A pound of digestible nutrients can usually be purchased in the form of beet tops for less than its cost in the form of any other stock feed common to the irrigated districts.

BEET PULP

The residue after the beet roots have been sliced and the sugar extracted by the diffusion process is called beet pulp. The gross weight of pulp obtained is approximately 25 percent of that of the whole roots. This pulp is used for stock feed in four forms—fresh, siloed, pressed, or dried. Fresh pulp is high in water content, is bulky to handle, and is used to only a limited extent. Siloed pulp is fed for several months following production, the feeding usually being completed by the following summer. Pressed pulp, from which a considerable portion of the water has been removed by passing between rollers, may be fed direct. It is often siloed after being moved to storage pits near the feed lots. Dried pulp is fed to livestock of all types, either as it comes from the drier or mixed with molasses; it is also mixed with other concentrated feeds to make a complete stock food. It can be stored for indefinite periods. Most of the dried pulp is fed in a dry state; however, it can be soaked before feeding.

It is the policy of many beet sugar companies to encourage feeding locally the greater part of the pulp produced at a

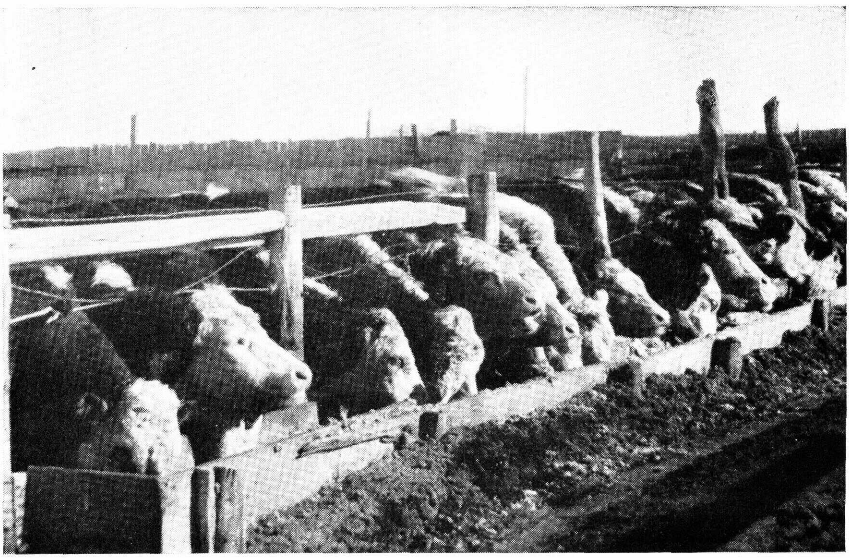

Figure 20.—Trough feeding of siloed sugar beet pulp to steers.

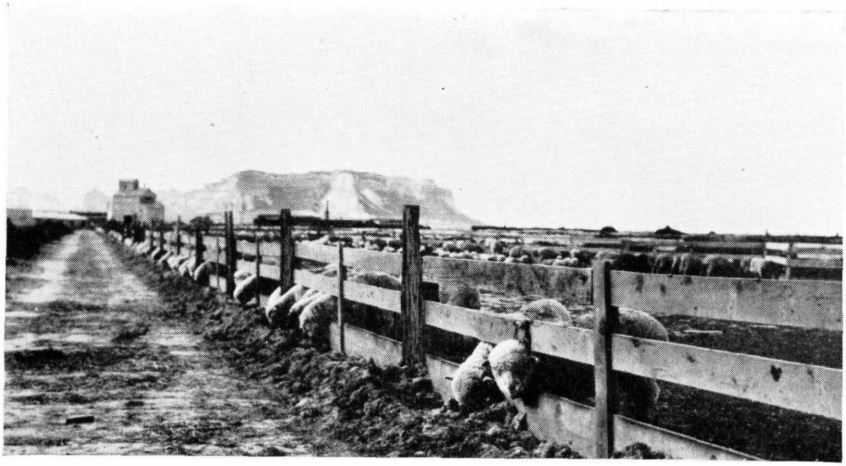

Figure 21.—Wet sugar beet pulp, a good feed for lambs.

factory. The livestock-feeding industry is thus fostered, and manure production for use on the beet lands is increased (figs. 20, 21, 22).

Fresh beet pulp contains approximately 90.5 percent water, 0.4 percent ash, 0.9 percent crude protein, 2.3 percent crude fiber, 5.8 percent nitrogen-free extract, and 0.2 percent ether extract, or fat. Siloed pulp has a higher percentage of dry matter, because the water drains out as the pulp stands in the pits. In general, a pound of dry matter in beet pulp has a feed value equal to a pound of dry matter in grain. Beet pulp is deficient in proteins, phosphates, and calcium; therefore, it should be fed in conjunction with legume hay, bonemeal, cottonseed

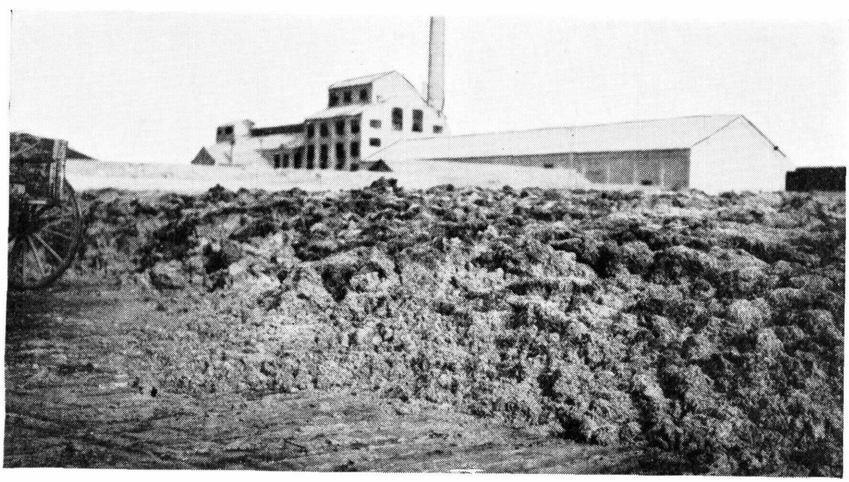

Figure 22.—Beet pulp in a pit silo at a beet sugar factory.

meal, or linseed meal. Recent feeding experiments show that where beet pulp and alfalfa hay are fed, bonemeal is a very profitable addition to the ration.

MOLASSES

Sugar beet molasses contains approximately 59.5 percent of digestible nutrients, made up of 3.5 percent proteins and 56.0 percent carbohydrates. Molasses contains approximately 5 percent potash salts, which have a laxative effect on livestock. From 3 to 5 pounds of sugar beet molasses may be fed daily to each 1,000 pounds of weight of livestock. Sometimes molasses is

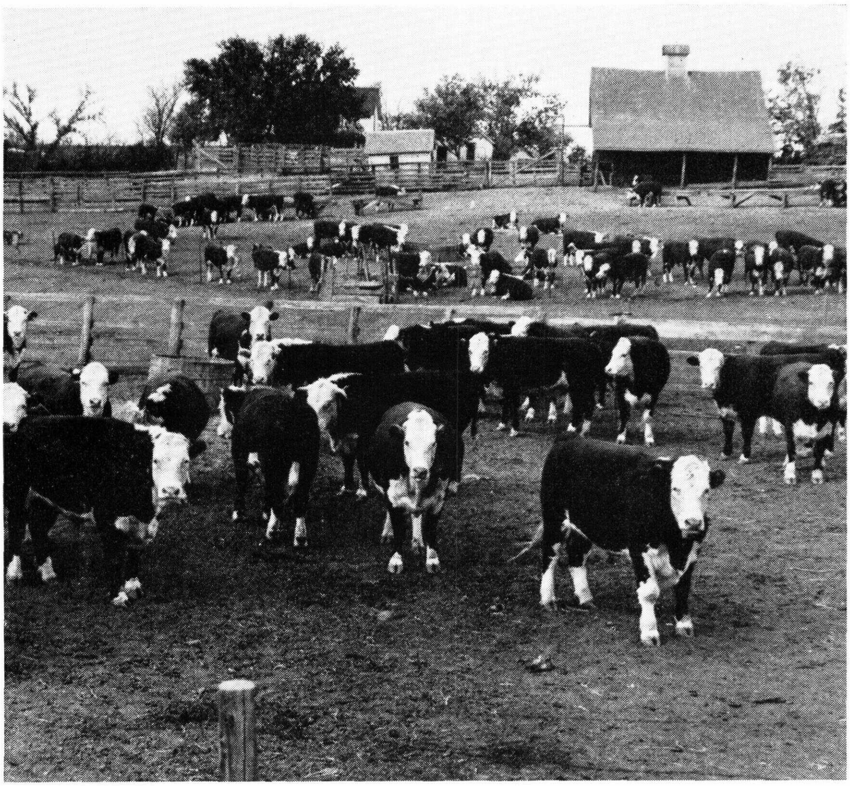

Figure 23.—Well-finished steers that have been fed for several months on a ration of grain, hay, and sugar beet byproducts.

fed alone, but usually it is mixed with other feed, such as hay, straw, corn stover, pulp, or beet tops. The palatability of all of the coarser feeds mentioned can be greatly improved by mixing them with molasses, and they are fed with much less waste than when fed without molasses (fig. 23).

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